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BUILDERS' HOISTING MACHINERY

Simple Lifting Tackle; Winches; Crabs; Cranes; Travellers; Motive Power for Hoisting Machinery

WITH NUMEROUS ILLUSTRATIONS

Edited by

PAUL N. HASLUCK

Editor of "Work," "Building World," etc. etc.

CASSELL & COMPANY, Limited
London, Paris, New York & Melbourne
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PREFACE.

THIS Manual contains, in form convenient for everyday use, a comprehensive digest of the knowledge of Builders' Hoisting Machinery scattered over seventeen volumes of BUILDING WORLD — one of the weekly journals it is my fortune to edit.

It may be mentioned that a series of articles from the pen of Mr. Joseph Horner is incorporated in the text.

Additional information on the matters dealt with in this Manual, or instruction on kindred subjects, may be obtained by addressing a question to BUILDING WORLD, in whose columns it will be answered.

P. N. HASLUCK.

La Belle Sauvage, London,
June, 1904.

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BUILDERS' HOISTING MACHINERY.

CHAPTER I.

INTRODUCTION: SIMPLE LIFTING TACKLE.

Hoisting machinery of some kind is indispensable to every building and contracting firm. The limits of human strength are soon passed, and the range of service of the common pulley blocks is very limited. When much heavy material has to be handled the employment of unsuitable hoisting machinery has a very marked effect on profits.

The principal kinds of hoisting machinery for builders and contractors are the following:—Pulley blocks; winches or crabs—single, double, and treble-geared, operated by hand or by steam, fixed on the ground, or made to travel on gantries; fixed warehouse cranes, whip cranes, wharf cranes, and quarry cranes, operated by hand; fixed derrick cranes, worked by hand or steam; steam hoists, or hoisting engines, made semi-portable, to do work in any locality, as the portable engine does for agriculture; travelling or portable cranes, operated by hand or by steam, for use in large yards and on wharves, with or without derricking arrangements for the jib; overhead gantry cranes, with jibs, worked by hand or power, used for similar purposes as the last-named, but moved on a high gantry clear of lines of rails and traffic beneath; jennies, overhead travelling cranes, or, more properly, crabs, destitute of jibs, used in

yards and in workshops, made in a wide range of powers, and actuated by hand, steam, or electricity; gantries, both fixed and portable, for travelling crabs, made in timber, iron, and steel; lifts in warehouses and shops, actuated mostly by hydraulic power.

In addition to the above-named, many other types of hoisting machinery are constructed; but the list given covers the whole range of that used by the builder and contractor. The construction of hoisting machinery has been revolutionised during the last quarter of a century, and goods and materials are moved, loaded, and discharged, and workshop and yard operations performed with a celerity little short of marvellous.

The present intention is to consider the machinery, not from the point of view of the maker, but from that of the builders and contractors who purchase and use it, so that instead of going extensively into questions of stresses and the calculation of certain dimensions, the types of cranes that are best adapted for certain kinds of work will be considered, and why they are so adapted will be explained. The weaker points of construction, the dangers incidental to working, the more vulnerable parts, the question of preservation, of repairs and renewals, of materials, workmanship, prices, etc., will be discussed, making the handbook a very practical guide for those who are not engineers. In a few instances, details of construction will be given, chiefly in the case of timber work, which can well be prepared in a builder's own yard, and in the case also of certain important details with which all crane users should be familiar.

The hoisting machinery used by contractors and builders is mostly operated by hand, or by steam. Much of this machinery, of course, cannot be constructed by any but an engineer. Yet there are some very simple types which can be made econo-

mically in a contractor's own yard—cranes and travellers, into the construction of which timber chiefly enters. There is also some of the plainer work which need occasion little difficulty, and there is also second-hand stuff which can often be bought for the price of old iron, and altered, and done up for temporary, or even for permanent service.

All hoisting machinery consists, essentially, of the framing and the gearing. The framing in a crane comprises cheeks or side frames, jib, tie-rods, and post; in a portable crane it also involves

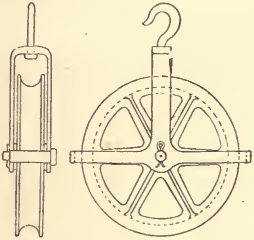


Fig. 1. Fig. 2.

Figs. 1 and 2.—Fixed Pulley.

the truck. In a crab, it consists of cheeks only. Timber, iron (both cast and wrought), and steel are used for these parts. Each is preferable in some cases to the others. The gearing comprises toothed wheels, barrel or drum, winch handles, shafts, clutches, brakes, etc., everything, in short, which is concerned directly with the hoisting and lowering of loads, and the slewing, travelling, and reversing motions of the machine. In single gear, there is but one pinion and one wheel between the winch and the barrel; in double gear, two pinions and two wheels; in treble gear, three

pinions and three wheels. Cranes, winches, and crabs of all types are manufactured with single gear, double gear, or with both single and double gear. Since with increase in power the speed is diminished, a keen foreman or employer will always insist that the attendant shall not use a high power for hoisting if a lower one will answer. Further, if a crane or crab is fitted with sufficient brake power, the load should always be lowered with the brake, and not by means of the gearing.

The simplest element in lifting tackle is the common gin-block, rubbish pulley, or monkey wheel (Figs. 1 and 2), the "fixed pulley" of the writers on mechanics. It is suspended by means of its hook from any convenient point of support, as a timber or other beam, a rope is rove over the sheave, the load being suspended from one end, and the hauling taking place at the other; while the frame prevents the rope coming out of the groove. The pulleys are made from 3 in. to about 22 in. in diameter. There is no mechanical gain in this, since a pull equal to the load must be exerted to maintain it in equilibrium. Its sole value, therefore, is that by its use a change in the direction of motion is conveniently effected, the direction of the pull—whether vertical or diagonal—not affecting the result. This type of pulley occurs in the crane in the jib-wheel, which changes the direction of the chain or rope at the head of the jib to the vertical. It occurs also in some derricking gear, in motion for racking a jenny along a traveller, and in other parts.

Two views of a common form of pulley-block are shown by Figs. 3 and 4. There may be one, two, or three sheaves in the fixed block, and the same number in the movable block. In each case the mechanical gain is estimated by the number of times the rope leads off from the lower or movable pulleys. If it leads off five times, as in the figure,

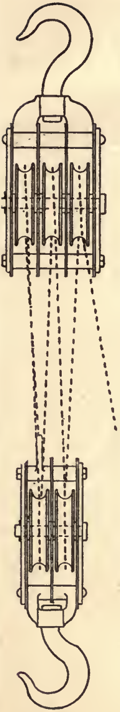


Fig. 3.

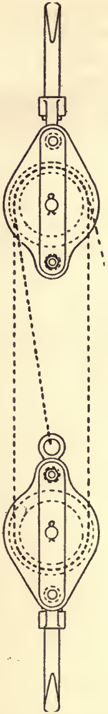


Fig. 4.

Figs. 3 and 4.—Common Pulley Blocks.

Fig. 5.—Differential Pulley Block.

the theoretical gain is 5 to 1. In practice it is considerably less than this, because of the friction.

The theoretical gain follows from the law of virtual velocities, or the principle of work; for in order that the lower block shall be raised 1 ft. the rope must be pulled out 5 ft.

Pulley-blocks are used in yards and factories for almost any class of work, being readily carried from place to place, and slung from beams and principals. They occur in heavy cranes, in the snatch-blocks, or return blocks as they are called, in which the pulleys may number one, two, or three. Owing to the different rates of motion of the various bights of the rope, there is much slip and friction between the rope and the pulleys. To obviate this, White's tackle was invented, in which the sizes of the pulleys are so proportioned to the velocities of the rope that no slip shall take place, and the friction of six separate pulleys is reduced to that of two.

The differential or Weston pulley-block (Fig. 5) does not run down of itself. The load has to be lowered by the chain as well as lifted. This is due to the excessive amount of friction developed—a property which might appear to be an evil—but one which actually contributes to the efficiency of the machine. The fixed pulleys are in one casting, and an endless chain passes over these and over the movable pulley below. The mechanical advantage is due to the difference between the diameters of the two fixed pulleys. Hence the rule: The power multiplied by the diameter of the larger pulley is equal to the weight multiplied by half the difference between the diameters of the larger and smaller pulleys. These pulleys are always used with chains, as ropes would slip; the sheaves are grooved out with recesses to take each individual link. Like other pulley blocks, they are slung from any convenient support. They will lift loads up to 3 tons or 4 tons; but they are necessarily very slow in their action.

CHAPTER II.

HAND CRABS OR WINCHES.

HAND crabs, or winches as they are termed (Figs. 6 and 7), are hoisting machines employed by masons and builders for hauling goods and material to the upper portions of buildings or of works

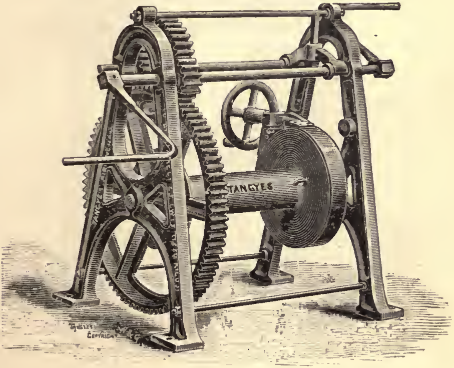


Fig. 6.—Hand Crab with Cast-iron Cheek.

in progress. Their convenience lies in their portability, a crab being moved easily from one part of a yard to another; shear legs, a beam, or a wall forms a convenient point of attachment for the sheave pulley (Fig. 1) over which the rope or chain which lifts the load is reeved.

They are made in many sizes, their power ranging from a single-geared winch lifting ½ ton, to a treble-geared winch lifting, perhaps, with double-sheave blocks and snatch-block, 25 tons or 30 tons.

These are also the cheapest kind of lifting tackle which can be purchased, the parts being extremely few. The cheeks of winches are made either of cast-iron (Figs. 6, 8, and 9), or of wrought-iron or steel (Figs. 7 and 10). The first are more liable to fracture when subject to rough usage, hence it is, in certain cases, as when in the midst of rough work, and when required for shipment abroad,

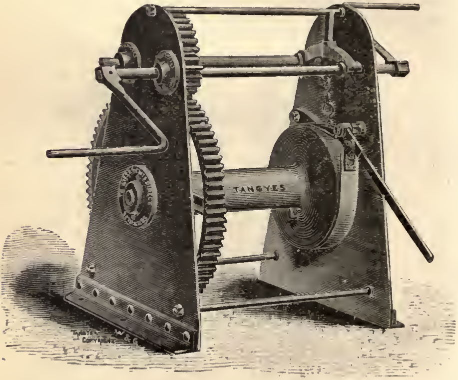


Fig. 7.—Hand Crab with Steel Cheek.

good policy to pay the higher price for the wrought-iron frames.

The neatest and strongest type in cast-iron is that in which a central web has double ribs on each side (Fig. 11). Sometimes the ribs are only cast on one side, as shown by Fig. 12. Where the distance stays or bolts pass through to connect the frames there should be thickening bosses coming flush, or nearly so, with the edges of the ribs. These are shown at A (Figs. 8 and 9). Framings other than of cast-iron are constructed with plate

and angle wrought-iron and steel. In the case of a light crab, the angle is riveted along the bottom edge only (Figs. 7 and 10). In large heavy cheeks the angle iron—in one strip—is bent round to the entire outline of the cheek, and welded up at one corner, and riveted on the plate. Examples of this kind will be given in due course.

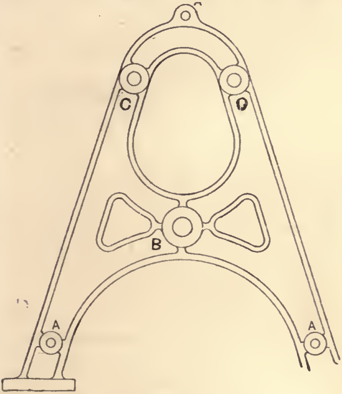


Fig. 8.

Fig. 9.

Figs. 8 and 9.—Cast-iron Winch Cheek.

When frames are plated, the shaft bearings cannot be formed in the frames as in Figs. 6 and 8, but must be made as separate cast-iron bosses, seen in Fig. 10, and riveted on the frames. Fig. 13 illustrates a boss to an enlarged scale, showing the mode of its attachment, A being the boss and B the framing. A portion of the boss is turned to fit a hole bored in the frame, and this, with the bolts, prevents movement. Fig. 14 is a section of the bearing shown by Fig. 13.

In winches exposed to the weather, all bearings should be bushed with gun metal, as shown in Figs. 10, 13 and 14, in order to prevent the undue abrasion or attrition which results from rusted surfaces in contact. The length of the barrel, and correspondingly the lengths of the shafts, will depend on the quantity of rope or chain which has to be coiled, but cost increases with length. All

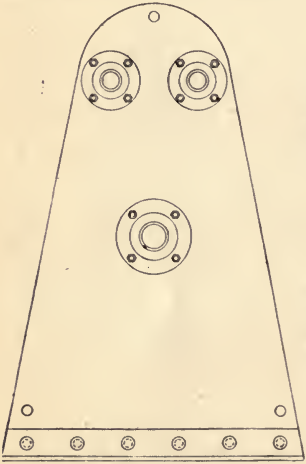


Fig. 10.—Wrought Winch Cheek.

Fig. 11.—Section of Cast-iron Cheek Ribbed Both Sides.

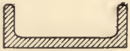


Fig. 12.—Section of Cast-iron Cheek Ribbed One Side only.

winches should be firmly bolted to a stout rectangle framing of timber to keep the frames from twisting in relation to one another; and the ends of the timbers which carry the frames should be extended 12 in. to 18 in. longitudinally to take the weights used for loading the hind ends to prevent the crab from overturning when at work.

These are the principal elements of construction occurring in an ordinary hand winch, and they occur in every crane, no matter what its type. The wheels and barrel, the shafts and bearings, and the brake, will be continually occurring as the more complex machines are considered, and it is necessary, therefore, to consider these in some detail.

In the gearing of a simple hand-crab all the elements which enter into the gearing of a 10-, 20-, or 50-ton crane are met with. The first is

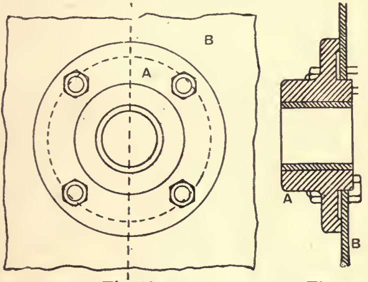


Fig. 13. Fig. 14.

Figs. 13 and 14.—Shaft Bearings.

a simple organism; the arrangements of the last are often more or less complex.

Fig. 15 is a scale drawing of a single-purchase crab, a perspective view of a similar machine being shown by Fig. 7. Fig. 16 shows a side view. The winch handles A A turn the first-motion shaft I, carrying pinion B, which drives wheel C, keyed upon the hoisting barrel or drum D, around which the chain or rope is coiled. The effective diameter of the barrel is the centre K of the rope or chain which is coiled around it. E is the ratchet or dog wheel, and F is its pawl. This wheel is keyed upon

the barrel shaft J, and therefore revolves with the barrel, the dog falling into each ratchet tooth in succession. The object of this mechanism is to prevent accidental over-running. Thus, if the load were to overpower the men at the handles A A, an accident would happen if the dog were not in gear with the ratchet. The dog being in gear, the running back of the wheels and chain would be prevented, as may be seen from the figures, in which the arrows show the rotation which corresponds with hoisting. The brake wheel G (H is its lever handle) is often placed within the frames, being cast on the wheel C, but it is a matter of no importance whether it is placed within or without. Its function is the lowering of the load. Before using the brake, the shaft I and pinion B are slid along in the direction of the arrow, the pawl or dog L being lifted off the shaft first, until the pinion is out of gear with the wheel C. Or else the pinion is left in gear and the handles A are taken off. Then the rate of lowering is controlled by the man at the lever handle H.

Looking at the arrangements, it is clear that there is gain in power between the winch handles A and the pinion B, and between pinion B and wheel C, and between wheel C and barrel D. Therefore,

Mechanical efficiency =

$$\frac{\text{Power applied to A} \times \text{radius } r \text{ of A} \times \text{radius of C}}{\text{radius of B} \times \text{radius of K.}}$$

Let radius r of winch handle A = 16 in.
Power of one man at handle = 15 lb.
Pinion B = 10 teeth × $1\frac{1}{4}$ pitch × 4 in. per diameter.
Wheel C = 76 teeth × $1\frac{1}{4}$ pitch by 2 ft. $6\frac{1}{4}$ in. diameter.
Effective diameter of drum = K = 7 in.

Then, taking the power of one man only—

$$\frac{15 \times 16\,\text{in.} \times 15{\cdot}1\,\text{in.}}{2\,\text{in.} \times 3{\cdot}5\,\text{in.}} = 517\,\text{lb.}$$

That is, one man, exerting a force of 15 lb. at A, can raise 517 lb., a gain of power of 34·4 to one.

Or two men can raise—

$$\frac{30 \times 16 \text{ in.} \times 15{\cdot}1 \text{ in.}}{2 \text{ in.} \times 3{\cdot}5 \text{ in.}} = 1035 \text{ lb.},$$

a gain of power of 69 to one.

But 15 lb. is a fair estimate, being based on the whole day's work of a man. It is found, in fact, that the work of several hours can be taken on a basis of 20 lb., and, for moderate spells, 25 lb. is a maximum estimate for the power of a man at a crane winch. So that the above figures may be increased safely.

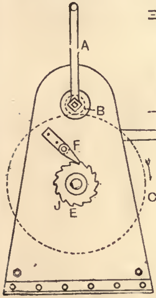


Fig. 15.

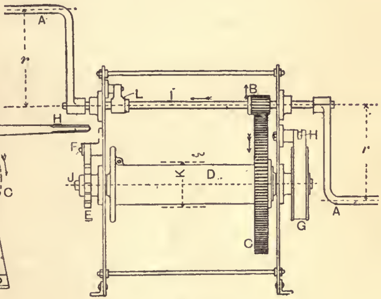


Fig. 16.

Figs. 15 and 16.—Single-purchase Crab.

The formula may take account of number of teeth instead of radius, thus:—

$$\frac{\text{Radius of winch handle} \times \text{power applied} \times \text{number of teeth in wheel}}{\text{Number of teeth in pinion} \times \text{radius of barrel.}}$$

There are two or three important facts which should be noticed in connection with this calculation. The smaller the divisor the greater the mechanical advantage. Hence, the smaller the barrel, and the larger the barrel wheel, the greater the power of the mechanism. It is seen that it

must be so, from the principle of work, that power is in inverse ratio to speed, that the slower the lift the greater the power which is being exerted. Also, the smaller the pinion the greater the gain. But the practicable limits in this direction are soon reached. If the barrel is made very small for a given size of chain, the links, which are to a certain extent rigid, are distressed. If the wheel is made very large, it occupies too much room, necessitating increase in the dimensions of the framing and other parts. If the pinion is made very small, it is also very weak, and so good a gear is not obtainable as with a pinion of moderate size.

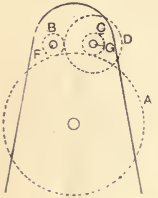


Fig. 17.

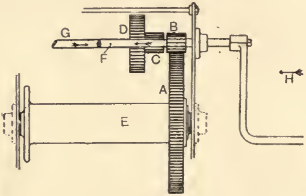


Fig. 18.

Figs. 17 and 18.—Double Gear for Crab.

If the radius of the winch handle is increased, the labourers exert their power at a disadvantage. As a matter of practice, winch handles have a radius of from 15 in. to 17 in. ; the smallest pinions seldom have less than ten or twelve teeth, and the largest wheels more than 100 or 120. But, bearing in mind the nature of the formulæ, by introducing intermediate gear, the power can be increased to a very large extent. A single intermediate shaft is the most common arrangement, but, in very powerful winches, two such shafts are sometimes used. Then the general formula would stand—

$$\frac{\text{Radius of w. handle} \times \text{power} \times \text{wheels}}{\text{radius of barrel} \times \text{pinions.}}$$

It is easy to see how enormously power can be increased in this manner.

Figs. 17 and 18 show the arrangement of double gear for a crab. The end view to the left in Fig. 17 is looking at the crab from the arrow end H. Here the shaft F is the first motion shaft, corresponding with the shaft I in Figs. 15 and 16, p. 21. It carries the pinion B gearing with A, as before, for use in single gear. For the double gear the second shaft G is used. This carries the pinion C

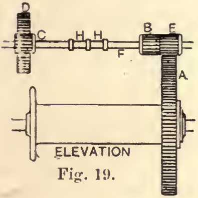


Fig. 19.

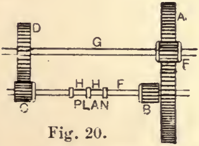


Fig. 20.

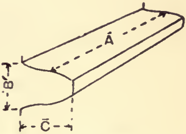


Fig. 21.—Wheel Tooth

Figs. 19 and 20.—Another Double Crab Gear.

and wheel D, cast together. To use the gear, the shaft F, with its pinion B, is slid out of gear in the direction of its arrow, and shaft B, with pinion C, is slid into gear with wheel A. These movements cause B to drive D, D carrying C with it, which in turn drives A. Pawls maintain the shafts in their end-long positions. E is the drum.

In many cases the gearing is not all arranged at one end, the arrangement differs in some instances, as illustrated in Fig. 19. The advantage

of the latter is that the pinions can all be flanged or shrouded, which is not practicable with the arrangement shown in Fig. 17. One more pinion, however, is necessary—pinion E in Figs. 19 and 20. This always remains in gear with A, and its shaft G is never slid along. The throwing in and out of gear is done with the shaft F. When B gears with A, C is out of gear with D, and the crab is running single-geared. Wheels E and D then simply run round, driven by A, doing no work. When C gears with D, B is out and A is driven through D and E, being then in double gear. H H are the grooves for the pawl to hold the shaft F endwise in either position. When the load is lifted by double gear, then the efficiency is about doubled, in ordinary cases, depending, however, upon the proportions given to the extra wheels. Suppose the extra pinions to number ten teeth and twenty-four teeth respectively, then the gain will be—the diameter of a twenty-four-toothed wheel of $1\frac{1}{4}$-in. pitch being $9\frac{1}{2}$ in., with one man,

$$\frac{15 \times 16 \text{ in.} \times 4{\cdot}75 \text{ in.} \times 15{\cdot}1 \text{ in.}}{2 \text{ in.} \times 2 \text{ in. by } 3{\cdot}5 \text{ in.}} = 1229;$$

or with two men,

$$\frac{30 \times 16 \text{ in.} \times 4{\cdot}75 \text{ in.} \times 15{\cdot}1 \text{ in.}}{2 \text{ in.} \times 2 \text{ in.} \times 3{\cdot}5 \text{ in.}} = 2458.$$

Another result follows also. Since the power of the arrangement increases while passing from the winch shaft to the barrel shaft, these shafts must be differently proportioned according to the work which they have to do. The wheels, moreover, must be stronger in the same ratio, the barrel-wheel and second-motion pinion being proportionately stronger than a first-motion pinion used only for single gear. This simple winch embodies a good many elementary principles; but better examples of these relations, as well as of sliding pinions, will occur in the cranes proper.

The strength of the teeth of wheels for slow-running cranes is generally calculated on a statical, and not on a dynamical, basis. Instead of reckoning horse-power transmitted, a tooth is considered as a cantilever subjected to a dead load. Then 8 or 10 is made the factor of safety.

The strength of a tooth (Fig. 21) is equal to:—

$$\frac{\text{depth } \mathrm{B}^2 \times \text{length } \mathrm{C} \times \text{strength of material}}{\text{breadth } \mathrm{A}.}$$

The tooth is considered a cantilever, loaded at the extreme end of the length C, that being the condition of maximum stress. As the teeth roll on one another, the pressure approaches the root, diminishing in amount. Since the depth B is the principal factor in determining the strength, teeth

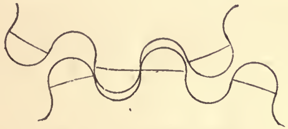


Fig. 22.—Cycloidal Teeth.

should never be made narrower than necessity demands, and a radius should always be cast in the roots. In small pinions, narrow roots cannot be avoided; hence the reason why large radii are generally cast in these, and why also they are often shrouded, or flanged. For the same reason partly, and partly because of the large amount of frictional wear and tear to which they are subjected, they are often cast in steel, phosphor bronze, and delta metal.

The teeth of the wheels of cranes are formed, as a rule, on one principle only, that known as Willis's odontograph. The typical tooth shapes are shown in Fig. 22, but those shapes vary, of course, with wheels of different diameters. The principle involved is, that any one wheel in a set

which is struck out by that method will gear with any other wheel of the same pitch. This is a most valuable property, inasmuch as it permits of the indiscriminate selection of wheels, and the building up of combinations of gears without the cost involved in making special wheels with teeth to gear with other special wheels. Into the technique of this it is not necessary to enter. Involute shaped teeth are seldom used, because it is not practicable to make good interchangeable gears covering a wide range of diameters with these.

A form of gear which is used rather extensively on cheap crabs is the knuckle gear (Fig. 23). In

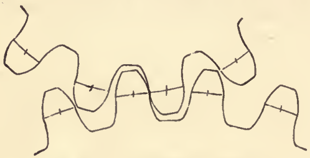


Fig. 23.—Knuckle Gear.

this there is not continuous rolling contact, as in the odontograph teeth, but it is nevertheless a very serviceable form, because, the flanks and faces consisting wholly of semicircles, the roots possess the greatest strength possible, and the points are never likely to become fractured in consequence of shock due to the wearing slack of shafts and bearings. They are, however, only to be recommended for small crabs, and not for large cranes, for which the odontograph tooth should always be used. Teeth should never be very long. The short teeth (Fig. 22) now coming into general use are to be preferred, because they are less liable to fracture in the event of sudden shock.

The gearing of cranes is made from patterns, and by machine. A practical man can generally

distinguish between pattern-moulded and machine-moulded wheels, by observing the teeth. But apart from that, the shape of the arms is an almost certain indication of the type of wheel. Figs. 24 and 25 are the arm shapes put in pattern wheels; Fig. 26, that used for machine wheels; almost the only exception to these shapes are the wheels with

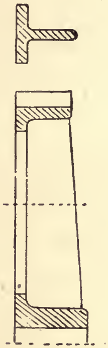


Fig. 24.

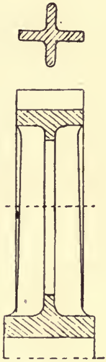


Fig. 25.

Figs. 24 and 25.—Arms of Pattern Wheels.

plated or disc centres, which are made either by pattern or machine. For the best crane work, machine wheels should predominate.

Unlimited power may be gained by the use of gearing, but, of course, the reduction in speed is in reverse ratio to the gain in power. Double gear, therefore, is seldom exceeded. Treble gear is so exceedingly slow that, though applied to not a few crabs and cranes, it is intended for exceptional rather than for ordinary duty. When, for regular service, power beyond the range of double

gear is required, it is desirable to discard altogether machinery operated by hand, and work the lifting tackle by steam, hydraulic, or electric power. Hence, pulley blocks and the crabs already dealt with are suited mainly for casual and occasional, and not for regular, work. Considerable range of power, portability, and cheapness, the fact that they require no kind of foundation, and can be operated by hand, strongly recommend pulley blocks and crabs, and make them popular.

Differential blocks range in power from ¼ cwt. to 4 tons. Single-purchase crabs will lift from 8 cwt. to 1 ton; double-purchase crabs from 16 cwt. to 4 tons. If, instead of lifting directly off the barrel, the rope is passed over sheave blocks, the

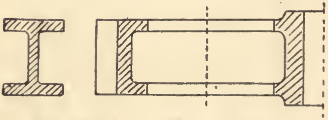
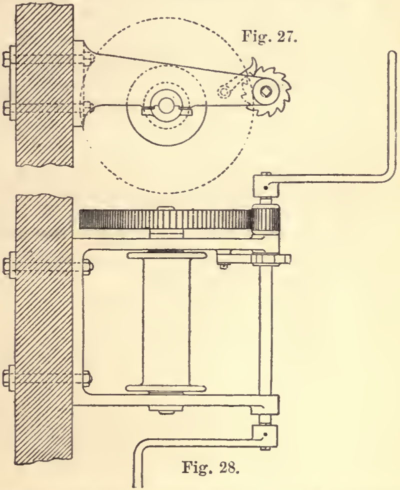


Fig. 26.—Arm of Machine Wheel.

power is increased about five times, but the speed is considerably reduced. Treble-purchase crabs will lift from about 6 tons to 15 tons direct from the barrel. Wire rope is used to an increasing extent for hoisting machinery, and when it is used with crabs the barrels should be larger than for ordinary rope, so as to avoid strain and stress. All crabs of the type so far considered are operated by hand. Steam is applied to ships' winches, but these are not under discussion. Steam is also applied to travelling crabs on gantries, a type that will be referred to later.

The gearing in the crabs already treated upon occurs in other kinds of hoisting machinery, of which that shown in Figs. 27 and 28 is a type. Winches of this special class are intended for

attachment to a wall for operating a jib crane, and also, variously modified, to Wellington cranes, and some gantry cranes for working the jenny from below. Wall jib cranes are used in warehouses and in workshops, where the framed crane carries no hoisting gear, but a pulley only at the jib head and at the rear. Or, when the crane has a hori-



Figs. 27 and 28.—Elevation and Plan of Wall Winch.

zontal jib only, the latter carries a jenny which is operated by the winch. Each of these forms is very useful, and each, while containing the essential gearing of the true crane, nevertheless differs therefrom in the separation of the hoisting gear from the main framing. Obviously, when a crane framing is attached to the outside of the wall of

a building, the gearing must be situated within the wall to be operated by the attendant. It is usual, then, to use an ordinary crab like those illustrated by Figs. 6 and 7.

The construction of many of the wall cranes is simplified by the use of a horizontal swinging jib with diagonal tie-rods above it, and by the use of a winch in a bracket bolted to the wall, as in Figs. 27 and 28. Single gear only may be used, as shown in the figures, or double gear. All the afore-mentioned crabs are of the fixed type—that is, though portable, they are fixed when at work. They must be suitably placed for the work they have to do, and they are fixed on the ground, or on staging, and not directly over the work. The larger travelling or overhead crabs are carried on low wheels upon rails laid on traveller girders, which girders are in turn mounted on end cradles and wheels to travel down a gantry, the gantry comprising beams laid parallel at a distance apart to suit the span of the crab.

CHAPTER III.

TRAVELLING CRABS, HAND AND POWER.

VARIOUS types of travelling crabs or travellers are used. In them can be studied many arrangements which either do not exist in the simpler fixed crabs, or which exist there in a very elementary form. In the simplest form of overhead traveller the common differential pulley block is suspended from a jenny. In others, again, the winch handles are dispensed with, and the load is lifted by a dependent endless chain. Many overhead crabs are provided with winch handles, and platforms are constructed for the men who turn the handles. The traveller or travelling crane comprises either a crab or a jenny which can be moved along beams or girders, while the entire structure can be moved bodily along gantry beams. By the combination of these movements, any load within the area covered by crab and gantry can be lifted vertically. The two dimensions which cover the area are the length of the traveller beams and the length of the gantry beams. The first will range anywhere between 10 ft. and 100 ft.; the second will be practically without limit. One gantry will very often be so long that several travellers will run upon it. These are always fixed gantries. They are either built up of timber framing from below, or are composed of square timber balks secured on the tops of wall buttresses, or on the tops of iron columns, or, for the lighter travellers, on corbels built into the wall. What are termed travelling gantries are the Goliath cranes, in which the crab rail-bearers are fixed on two vertical framings, the whole structure travelling bodily along rails laid on the ground level.

Travelling crabs may be broadly classified in two groups: (*a*) overhead travellers operated by hand, and (*b*) overhead travellers worked by power. In class (*a*) the travellers are worked either from below or from above, those worked from below being generally light, lifting from 1 to 5 tons, though travellers with a lifting capacity of 15 or 20 tons are sometimes worked in this manner. Travellers of this class are numerous, cheap, and are suitable for yards and sheds where there is not enough work to keep a man specially for hoisting. The motions are operated by endless ropes or chains passing over sheave pulleys of large diameter, having V-rims to ensure a good bite. One rope serves for hoisting and lowering, and another for cross-traversing. The down traversing in the smallest traveller is not done by gear, but simply by pulling at one of the ropes in the direction in which movement is required. In the heavier hand travellers, however, operated from below, the longitudinal traverse is worked by gear. The endless rope operating its V-grooved wheel turns spur pinions and wheels, the latter being on two of the travelling wheel axles. In the heaviest hand travellers worked from below the use of treble purchase gear is necessary for lifting maximum loads, and two chain or rope wheels are necessary, one on each end of the first motion shaft, in order that a couple of men shall be able to operate each rope.

The majority of hand travellers are travelled down the gantry either from the crab through a square shaft, or by means of gearing placed on one cradle.

In the Goliath cranes, in which crabs run on travelling gantries, it is customary to travel by means of gear placed at the base of the end framings. In a few cases this travelling is effected from the crab through bevel gearing and shafts

There are several different types of power travellers. The first comprises travellers which run on fixed gantries; the second travellers, or Goliaths, which run on travelling gantries. In the latter case the gantries are moved by hand by men stationed below, as in the hand Goliaths; or they are moved from the crab, and by gearing which is attached, to travel along with the crab.

Power crabs are operated by steam and by electricity. Steam is a very popular and long-tried and proved motive power. In such travellers, crab and traveller are operated by means of an engine and boiler fixed on the crab, and moving with the crab; but sometimes the boiler and engines are fixed at one end of the traveller beams, and the crab becomes then a mere travelling jenny. Fixing the boiler and engine at one end of the traveller and driving through a jenny has the advantage of lessening the load on the traveller beams by the extra weight of the crab, which will often equal or exceed that of the load to be lifted. More than that, there is less surging of the traveller than occurs when the dead weight of the crab becomes a rolling load.

The details of construction of steam crabs differ considerably from those of hand crabs. The employment of engines and boiler necessitates a larger and more substantial framing. The engines are bolted to the framings on the outside, leaving the inside free for gearing. The boiler is placed at the back or on a foot-plate, from which the attendant operates all the motions, the handles for which are brought within convenient reach. A water-tank, through which the exhaust steam passes warming the feed water, is placed under or at one side of the boiler or in front of the crab. The whole of the crab should be protected from the weather by a house of corrugated iron.

Steam crabs carry their boilers and engines.

In steam crabs also provision is generally made for operating the gantry, when the latter is of the travelling type, directly from the crab through shafts and gearing. If the power is carried to the crab through a cotton rope, then a shaft running along the traveller drives the crab in all its motions.

Other forms are Wellington cranes and Goliath cranes, of which large numbers are used. The first named are operated by gearing placed on the verticals, and actuating a jenny, and are often

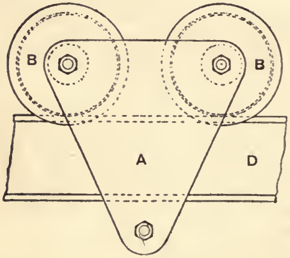


Fig. 29.

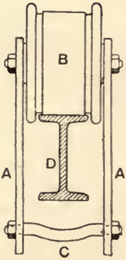


Fig. 30.

Figs. 29 and 30.—Jenny for Traveller Blocks.

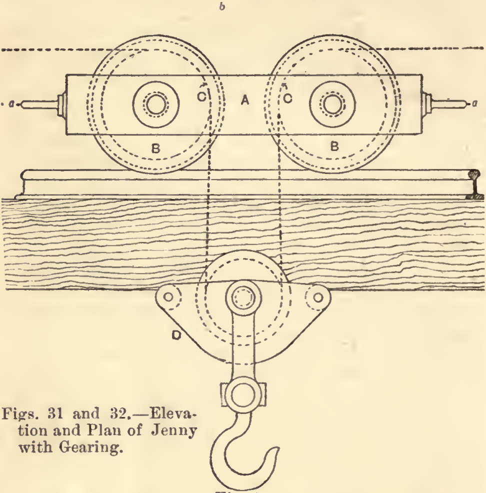
termed travelling gantries. The second are crabs mounted on the horizontal girders, driving the entire Goliath in all its motions, and may be worked by hand or by steam.

For light haulage, whether in yard or workshop, the overhead traveller with a jenny for the attachment of differential blocks is very convenient. Its drawback is that the action of the block is very slow, and, of course, the load is somewhat limited. The limit is about four tons, being equal to the capacity of the largest blocks.

For light jenny travellers the girders are simply

rolled H-joists D (Fig. 29). B B are the runners, and C serves for the attachment of the pulley blocks. Another view of the jenny is shown by Fig. 30. For heavy loads and large spans timber beams are used, or else built-up girders, either parallel, or more generally fish-bellied and single-webbed in all but the heaviest, which are sometimes double-webbed. With the single girder used for the runners of the jenny the limit of span is about 18 ft. The traveller itself in the smallest sizes is pulled along the rails by hauling at the end of the suspended block, but in the larger sizes movement is effected by means of an endless chain passing over a sheave wheel on a longitudinal shaft, having a pinion at each end, gearing with spur wheels keyed on one of the running wheel axles. The end cradles are made either of wrought-iron or of cast-iron. When cast-iron is used, the traverse girder is socketed into the castings and cemented, the cement consisting of iron borings and sal-ammoniac; a single bolt is inserted for extra security. Jenny crabs are made to lift loads from half a ton to twelve tons, and in span up to about 20 ft.

Figs. 31 and 32 show a plain jenny which travels on double traveller rails. The whole of the gearing by which it is actuated is placed on the verticals of the travelling gantry, and may be single or double. One set of gearing serves for racking the carriage along, another set for hoisting and lowering, guide pulleys being placed at the ends of the gantry beams. In Figs. 31 and 32 there is a jenny carriage A, made of cast-iron, running on four double-flanged wheels B B B B. The carriage is pulled along in either direction by means of a chain hooked to the eyes *a a*. The top of the chain passes along at *b*, and its connection with the carriage make it endless, the bights passing over pulleys—one at each end of the gantry. The lift-



Figs. 31 and 32.—Elevation and Plan of Jenny with Gearing.

Fig. 31.

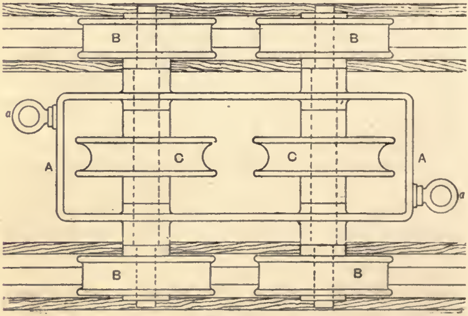


Fig. 32.

ing chain passes over the pulleys C C. This is anchored at one end, and passes over a pulley at the other, operated from the hoisting barrel on the vertical below. The power is doubled by the use of a fall or snatch block D, a device adopted in all except the crabs of lowest power. In a con-

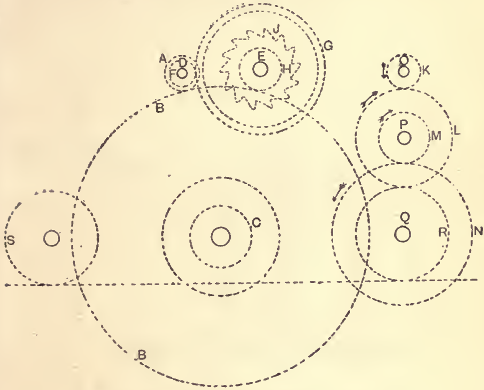


Fig. 33.—Diagram of Overhead Crab Gear.

tractor's yard where hand power only is used, there is nothing handier or cheaper than this arrangement. Everything is operated from below, and only for oiling or repairs is it necessary to send a man up on the gantry.

Although the jenny is a simple arrangement, yet it is so valuable that it occurs in various forms, in some of the most elaborately devised cranes of high power, even up to fifty tons. It is often found more convenient to locate the hoisting tackle away from the travelling jenny instead of upon it,

as in the true or self-contained travelling crabs, to which consideration will be given.

The gear for a typical overhead crab is shown in Figs. 33 to 36. It will be observed that there are two sets of gear, one for hoisting the load, the other for propelling the crab along the rails; and all travelling crabs, with the exception of those types already mentioned, have such distinct

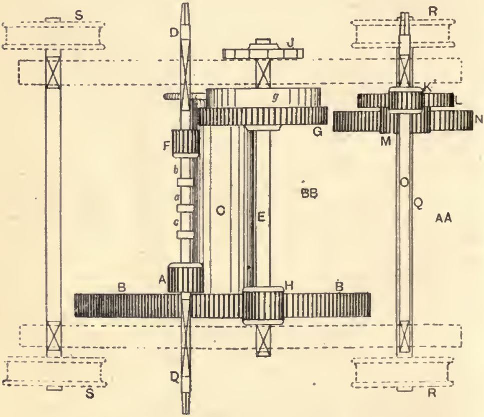


Fig. 34.—Plan of Overhead Crab Gear.

sets of gear. But these gears are subject to very great modifications in crabs of different kinds, which modifications can be better studied after discussing the typical and very common arrangement illustrated by Figs. 33 to 36. Details of frames, bearings, etc., have been omitted, in order not to crowd and obscure the essential gearing, which is shown with full lines.

Both the hoisting and the travelling gear are double, few overhead crabs being made with single gear only; it is entirely hand-operated, by a man, or men, standing on a platform attached to and travelling with the crab. As far as this particular gear is concerned, there is no provision for moving the traveller itself along the gantry; where such provision is made the methods of effecting such movements differ from each other considerably.

In Fig. 33 the pitch circles of the various wheels

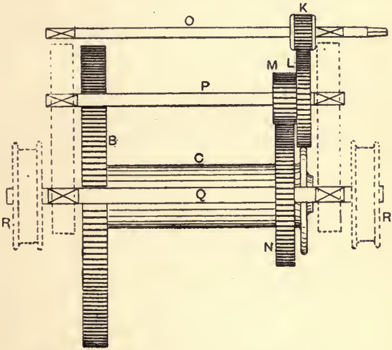


Fig. 35.—End View of Overhead Crab Gear.

are shown in elevation; in Fig. 34 wheels and shafts are seen in plan, the positions of the shaft bearings being indicated by diagonal crossing lines; Fig. 35 shows the travelling gear in end view from the position A A in Fig. 34; and Fig. 36 shows the hoisting gear only in end view from the position B B in Fig. 34. In these figures the pinion A and wheel B are used for quick lifting. A is keyed on a sliding shaft D, the endlong movement of which can be arrested by means of the pawl

grooves *a*, *b*, *c*, either in a position *a* of no gear, as shown, for lowering by the brake; or at *b*, with pinion A in gear with B; or in *c*, with pinion F in gear with G. When A gears with B, the latter, being keyed either upon the barrel C or upon its shaft E, lifts a light load quickly. To lift a heavy load slowly, the shaft D is slid along until F gears with G, the pawl dropping into C; F then drives G on the same shaft as the pinion H, which in turn drives the wheel B on drum C. The relative rates are, in the first place:—

$$\frac{\text{Power} \times \text{radius of winch handle} \times \text{B}}{\text{A} \times \text{C}}.$$

In the second case:—

$$\frac{\text{Power} \times \text{radius of winch handle} \times \text{G} \times \text{B}}{\text{F} \times \text{H} \times \text{C}}$$

The dog is kept in contact with the ratchet wheel J during the lifting, so that, in the event of any mishap occurring, the ratchet will hold the load. When it is desired to lower by brake *g* on the wheel G, the pawl is thrown back, the shaft D is slid into its middle position, the winch handles detached or the men stand clear, and, the pinion H always remaining in gear with B, permits the load to be lowered safely by friction, due to the pull on the brake strap embracing *g*. The travelling gear is, as a rule, only provided with one set of motions, either single or double, in the latter case without any provision for alteration. In the figures shown the travelling gear is double only; K is the first pinion driving wheel L, next which is keyed or cast the pinion M, which in turn drives wheel N, keyed on the same axle Q as the driving running wheels R, R. O and P are the shafts of the pinion K and wheels L and M respectively. The driving is done only on one pair of wheels R R, the other pair of wheels S S trailing simply. In the heaviest steam crabs the front and rear wheels are coupled with rods, to distribute the load

equally. But this is never done on hand crabs. Hand-operated overhead crabs lift up to about 20 tons, but the majority do not exceed 10 or 12 tons. Spans will range up to 40 ft. or 45 ft.

Overhead travelling crabs are constructed in various ways. Cheeks are made of cast-iron, or are plated, as in the fixed crabs. Two views of a cast-iron cheek are shown by Figs. 37 and 38. When plated, the web is sometimes made of thick

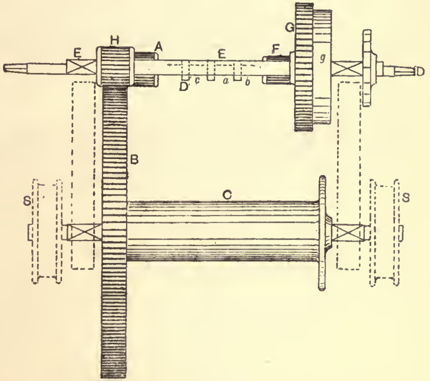


Fig. 36.—Overhead Crab Hoisting Gear.

plate, and only a bottom flange riveted on; the web is made of thin plate, and flanged all round. The latter is preferable to the former, because the frames are stiffened materially by the riveting of an angle iron round them, and because the angle forms a suitable basis for bolting shaft bearings. When the angle is riveted to the bottom only, then boss bearings are necessary, and these contain no provision for the taking up of wear as divided

bearings do. Moreover, boss bearings are considered rather objectionable in crane work, because whenever a shaft has to be removed, as, for instance, to replace a fractured pinion by a new one, often one cheek at least has to be taken away bodily, since there is no other way to remove any shaft. Bosses are cheaper, of course, than divided bearings, but they give trouble subsequently. When boss bearings are used, it is desir-

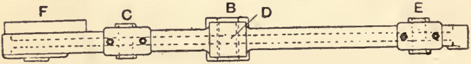


Fig. 37.

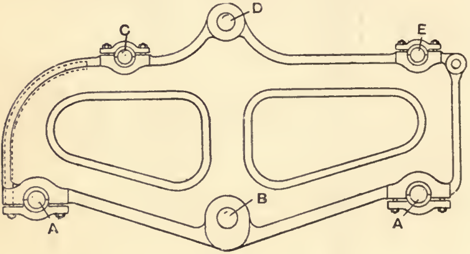


Fig. 38.

Figs. 37 and 38.—Cast-iron Cheek for Hand Crab.

able to arrange shaft diameters so that the shaft can be drawn out endwise. Then it is usually practicable to key a small wheel on the shaft when inserted part of the way through the frames.

The frames of many of the heavier crabs are of a composite character, being made mainly of plating, but having cast-iron cheeks bolted on to carry the main shafts, a single casting carrying two or three distinct bearings. This facilitates the fitting and boring of the bearings, and generally

makes a more rigid framework. But it is not often adopted in small crabs.

Figs. 37 and 38 illustrate a cast-iron cheek for a hand crab, and Fig. 39 one of wrought-iron or steel. The first contains provision for single travelling gear only, the second for double gear.

Cast-iron being a rather brittle material, is liable when used in crane work, to fracture under the sudden and severe stresses which often occur in braking and in slipping of the chain and surging of framings. Many cast-iron framings are

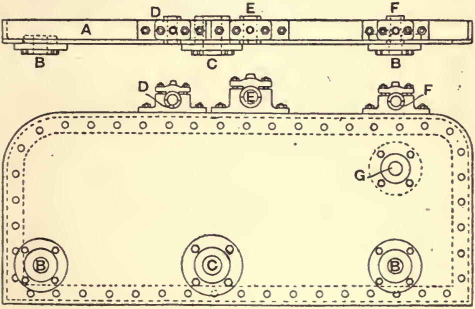


Fig. 39.—Wrought Cheek for Hand Crab.

much lighter than they ought to be, or the metal is badly arranged, and angles are left too keen. But if well proportioned and designed, cast-iron frames are more rigid than those of wrought-iron, and the expense involved in fitting angle irons and in the attachment of separate bearings is saved, because the bearings are made in the casting itself.

Figs. 37 and 38 show a well-proportioned frame lightened out in the vicinity of the neutral axis, and well ribbed everywhere with good radii. A A

are the axle bearings, B is the barrel bearing, C is the bearing for the first motion pinion shaft, D that for the intermediate and brake-wheel shaft, and E that for the first motion travelling pinion shaft. A A C E are divided bearings, B and D are solid. The metal below B and in the ribs adjacent is thickened because it is in tension, which cast-iron is weak to withstand. The divided bearings are in cast-iron as shown, or lined with brasses. Brass bearings are not so desirable in slow-running hand crabs as in steam crabs. Often, however, brass is used for the bearings C and E, even in hand crabs, because they are of small bore, and the shafts revolve several times faster than those in the other bearings. A curved rib is cast on at F. The object of this is to receive a piece of sheet iron which is bolted to it, extending from cheek to cheek, and which receives the bearings for the pawl.

In the wrought-iron or steel cheek (Fig. 39) the angle A, bent to the outline of the cheek, should properly be welded up into one piece rather than be made in separate pieces mitred at the corners. It is riveted, the rivets being spaced at from 3-in to 4-in. centres ; B B are the axle bearings, C is the barrel bearing, D the bearing for the first motion pinion shaft, E the bearing for the intermediate shaft, F the first motion travelling pinion shaft, G the intermediate travelling shaft, the gear being double. The bearings B B C G are boss bearings, which pass through holes bored in the frame, being bolted to the frame through flanges. D E F are ordinary plummer blocks bolted to the angle. All or any of these bearings may be in iron, or brass bushed. Such a frame depends for its stiffness more on the size of angle, and the method of its fitting and riveting, than on the thickness of the plate. The fitting of the bearings also must be good quite apart from the holding power of

the bolts. The portions of the bosses which project through the frames should be turned, and fit closely into holes bored in the plate. The bottoms of the plummer blocks should be planed, and a light rough cut be taken off the top angle. Bolts must be turned, and bolt holes drilled. These are the essentials of good fitting in such a cheek.

In the true travellers, the main bearers are supported at their ends by means of cradles, which are short beams attached to, and at right angles with, the main bearers. These are provided with flanged wheels, which travel down the rails that are fixed to the gantry beams. The essential framing is that consisting of a couple of parallel main beams, supported at the ends, and loaded at intermediate points with the crab and its load; and two cradle beams, supported near the ends, the wheels being the points of support, and loaded at two intermediate points by the main beams and their load.

The method of calculating the strength of these beams is similar to that employed for beams in general. As will be shown later, the forms and sections used in their construction differ very widely. The first essential in these, after absolute strength, is stiffness, not only depthwise, but sideways. The beams cannot be tied anywhere except at the ends, because there must be a clear-way between for hoisting. They must therefore be stiff enough in themselves. This stiffness is imparted in various ways—in some cases by utilising a platform girder ranged alongside the main girder, and connecting the two together. For single-webbed beams the top and bottom flanges are made sufficiently wide to impart side stiffness. In heavy travellers, the double-webbed or box form of girder is used; in these the two webs reinforce each other, and the flange plates are wide.

Another difficulty to be guarded against is that

of cross-working of the traveller. The longer the span, the more liable is the traveller in going down the gantry to irregular diagonal movements, and this causes hitching and fracture of the flanges of the wheels. Such accidents are generally prevented by the use of a broad wheel base (that is, distance from centre to centre of wheels) on the cradle. There can seldom be any objection to a long wheel-base, and the length should be in due proportion to the span of any traveller.

Another matter which is not always under control is the method of attachment of the main beams to the cradle beams. If there is sufficient headroom, it is always best to bolt the ends of the former directly on top of the latter, because of the intensity of the bending moment over the ends. It sometimes happens, however, that this method is not available, because it would not leave sufficient head-room for the crab. In such case one of two devices is available: either place the cradles over the ends of the main beams, in which case the whole stress on the latter has to be sustained by bolts; or abut the main beams against the perpendicular faces of the cradles and rely on bolts and rivets. But lightness as well as strength is required in a crab and traveller, even more than in a crane. The dead weight of the crab and traveller is nearly always greater than that of the load to be lifted. Hence, while ample strength and stiffness should be provided, the minimum of weight consistent with stability should also be secured. Some travellers are much heavier than they need be, not because they are unnecessarily strong, but owing to bad designing and injudicious arrangement of material.

In another class of crabs and travellers driven by steam, the engine and boiler are located in a building elsewhere, and the power is transmitted by means of a longitudinal line of shafting running

down one wall of the shop, in a line with the fixed gantry. This drives a square shaft along the traveller girder on which the crab moves, and operates the motions of the crab through worm gearing or bevel wheels. This movement is the reverse of that in which the crab is made to drive a travelling gantry, and there is little essential difference in the methods by which these movements from traveller to crab, or from crab to traveller, are transmitted.

Instead of using a square shaft along the gantry, a cotton rope running at a high speed is a favourite method employed to transmit power from a distance to the traveller. When electricity is used as the motive power, then the dynamo is situated in any convenient locality away from the traveller, and a rod conveys the current thence alongside the gantry, whence it is taken up by a brush on the crab connected to the electric motor. Then belt gearing is used to reduce the speed as required.

The motions of many overhead travellers are operated from one end, from levers brought to a cage within which the attendant sits. The method is applied to crabs actuated by square shafts and cotton ropes, and to jenny crabs operated by either method. The advantages are that the maximum of head room is obtainable in this way, more especially when a jenny is used, and that the attendant can from his cage see the work below much better than from a platform on crab or traveller. Such an arrangement consequently is used very extensively.

CHAPTER IV.

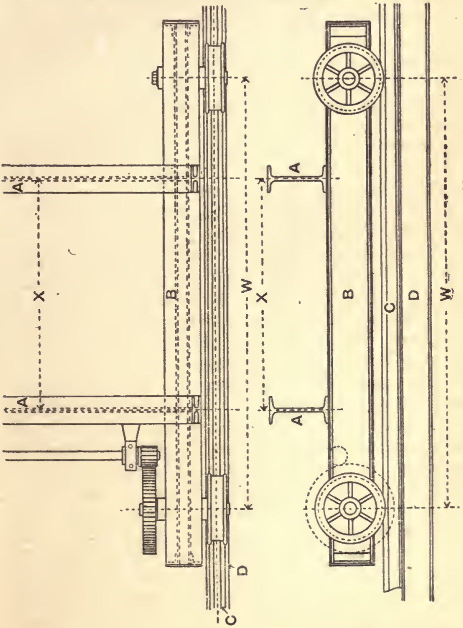
CRANES AND TRAVELLING CRABS: THEIR DETAILS OF CONSTRUCTION.

THE framework of a traveller consists of main beams or girders with or without truss rods, and end cradles with their attachments. Timber may be used for the beams, in which case trussing is necessary. Timber gantries are well adapted for contractors' use, and are cheaper than those made of iron or steel; but for permanent structures, and for shipment abroad to hot countries, iron or steel is always to be preferred. The use of timber for beams is economical in the case of builders and contractors, because the timber work can be constructed in the yard; a crab can be bought new, or cheaply at second-hand, and the gantry made to suit the firm's requirements. The timber gantry must always be trussed, but in ironwork trussing is not indispensable.

For light work the rolled H-joists make good beams, and for the heavier class of travellers the beams are built up of plate and angle iron in such a way as to be self-sustaining. The strength is obtained by increasing the depth of the parallel girders, or by making girders of fish-bellied form, suitable stiffeners being inserted to prevent buckling. Travellers intended to lift light loads and with narrow spans are generally made with girders of rolled H-sections; they are cheap, and the absence of truss rods gives increased head room.

The riveting of the rails to the girders increases their stiffness, and sometimes plates are riveted to the top and bottom flanges with the same intention. Traveller beams of H-section are occasion-

ally used for wide spans, in which case they are generally trussed. The struts may then be formed of flat bars riveted to the sides of the beams, the truss rods being flat bars. This method of construction is desirable when lightness is sought in



Figs. 40 and 41.—Light Traveller Framing.

long-span travellers. Such joists can also be trussed with round rods, cast-iron struts being bolted to the bottom flange or to blocks of timber inserted between the flange and strut.

Illustrations of some types of iron and steel girders used on travellers are given by Figs. 40 to 42. Figs. 40, 41, and 42 show the cheapest type of framing for light travellers used for geared crabs, Fig. 40 being a plan of one end, Fig. 41 an end view, and Fig. 42 a side view. The main girders consist of two joists A A of H-section upon which the crab travels on rails, and two end cradles B which support the joists, and travel on rails C down the gantry beams D. The supports of the gantry may consist of continuous beams if in a yard, of masonry corbels if in a shop, or of continuous timber beams upon or against the walls. In these figures the cardinal dimensions are the span or distance from centre to centre of gantry rails, the wheel base W of the end cradles, and the centres X of the crab wheels.

These dimensions vary widely as the requirements of a firm vary, but they are the main elements in the settlement of the other dimensions, and also of the general methods of construction adopted. The first and most important is the span; on this depend the depth and cross-section of the joists A A, and also the question of the employment of joists at all, or of the more elaborately built-up girders of plate and angle. There is no rule limiting the use of joists on the one hand, or of plate girders on the other. At extremes there is no question as to the most suitable selection, but in a large number of cases local conditions must determine the choice. Joists can be had up to 12 in. deep at ordinary prices, and they can be superimposed to increase depth. But, in the latter case, dead weight becomes unduly increased, and plated girders can be built of less weight with equal strength.

For light travellers, however, joists are cheaper and quite as good girders. The wheel base W should be of a good length, the governing con-

dition being the prevention of cross working. The larger the span, therefore, the more reason is there for increasing the wheel base. The wheel base, and the weight of the girders A A, of the crab on them, and of the maximum load lifted, together determine the depth and sectional area of the end cradles B.

With increase in span and load the rolled joist gives place to built-up girders. These are either parallel or fish-bellied, single- or double-webbed. They are parallel for short spans and moderate loads, bellied in other conditions. The advantage of the latter consists in the attainment of the maximum strength with the minimum of dead weight. It is a form, therefore, adopted for most heavy travellers of long span. It is, of course, essentially a double parabolic outline, but this is for practical purposes merged in a regular curve.

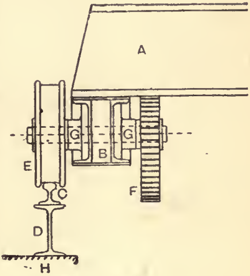
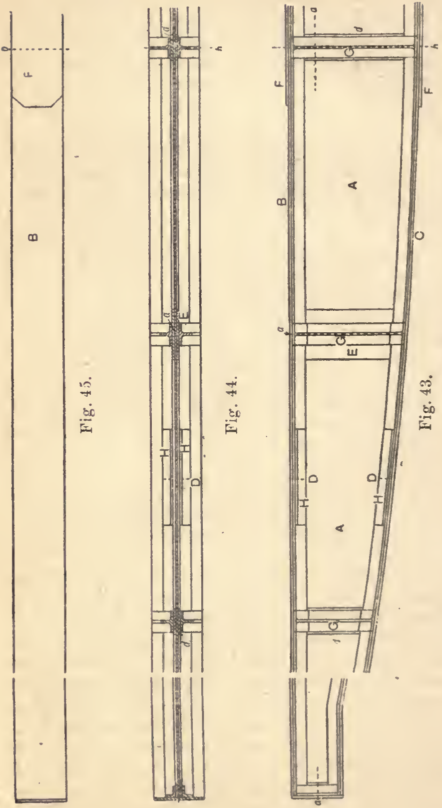


Fig. 42.—Side View of Light Traveller Framing, etc.

Figs. 43 to 46 illustrate a girder of this type, the numerous rivets being the only omission. Fig. 43 is a half elevation, Fig. 44 a longitudinal section on the plane *a a*, and Fig. 45 a plan view on the top flange to which the crab rails are attached. The girder is solid-webbed and single-webbed, as shown in section in Fig. 46. The web A is in two, three, or more lengths, dependent on the total length and depth of the girder. In Figs. 43 and 44 there are three plates, jointed at *a* on each side of the centre. The top and bottom flange plates



Figs. 43 to 45.—Built-up Girders for Traveller Framework.

and the angles also have to be jointed. These parts always break joint. The top flange plate B and the bottom one C are each in two lengths in this example, and jointed at *b* midway between the web joints *a*. At D the angles break joint away from both *a* and *b*. At each joint there are covering plates; E E for the web A; F F are covers for the flanges B and C, while the angle joints have covering angles H H. In all such joints the area of the covering pieces and the rivet section must be ample, and the joints must be arranged wide apart. At certain intervals stiffeners G G G are riveted down the girder webs. Without these the webs would crumple and twist out of shape, even though strong enough as beams by calculation.

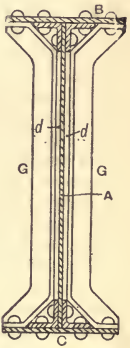


Fig. 46.—Section of Girder.

To make the beams rigid enough without stiffeners, it would be necessary to increase the web thickness A, thus adding by perhaps 50 per cent. to dead weight. By the use of these stiffeners or struts placed at intervals of a few feet apart, the thin webs (rarely exceeding from $\frac{5}{16}$ in. to $\frac{7}{16}$ in. in thickness) are amply reinforced and buckling is prevented.

The stiffeners are usually of T-section, though angles are often used. They may be set up close to the web A, but the usual practice is to lay them against packing pieces *d d*, which cost no more than the setting of the angles, while they add to the rigidity of the web. At a web joint as at *a*, the joint plates E serve also as packings. The method of setting out the stiffeners, seen in section in Fig. 46, is better than simply joggling the

stiffeners over the longitudinal angles, because some extra support is thereby afforded to the flange plates.

The construction of the joints of parallel girders is identical with that illustrated in the fish-bellied girder, and need not therefore be shown separately. Parallel girders cost less per ton than bellied ones, and are frequently employed. But as span and weight increase, it is always better, in order to secure lightness combined with maximum strength, to supply the bellied form, a practice which is rarely departed from. For the widest spans the box girder is usually selected. This is essentially two single-webbed girders placed at a distance of from 6 in. to 10 in. apart, and rigidly connected with flange plates. These are much superior to the single-webbed form, because they are much more rigid to resist the side deflections due to the irregular movements of the crab and its load when working. The main beams cannot be braced together at any point away from the ends, the most that can be done in some cases being to insert gussets at the union of the main beams with the cradles. They are therefore entirely independent, and must be rigid enough in themselves to withstand side deflections, as well as those in a vertical direction, and for this reason the box girders are preferred for long spans and heavy loads.

The end cradles of travellers are made of timber, cast-iron, wrought-iron, or steel. Timber and rolled H-irons are employed for light travellers, cast-iron often for those of moderate weight, and structures built up of wrought-iron and steel for the heaviest. In each case cast-iron bearings, either solid or divided, are employed to carry the gantry wheels. In most instances the traveller beams are bolted on top of the cradles, an arrangement which is very suitable, and which gives the maximum of head room. Occasionally it is neces-

sary to reverse this by bolting the beams below the cradles, as when the roof is too low to permit of the usual arrangement; in other cases they are bolted against the cradles.

Fig. 47 shows an end cradle of cast-iron, suitable for jenny travellers, lifting up to about 1 ton or 30 cwt. A is an H-joist, along which travels the jenny from which pulley blocks are suspended. B is a casting suitably cored, and C C are the

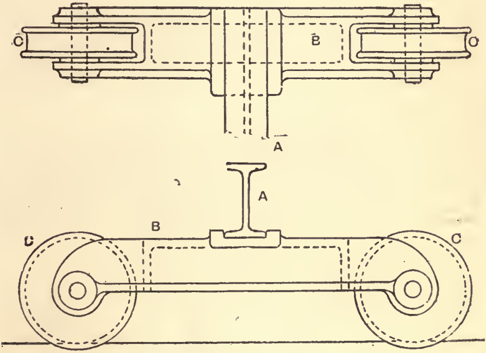


Fig. 47.—End Cradle for Jenny Traveller.

gantry wheels keyed on axles which run in bearings in B. This form is cheap, light, and strong enough for its purpose. The jenny used on such a traveller is shown by Fig. 29, p. 34.

In Figs. 40, 41, and 42, a cheap form of cradle is shown. The cradle B is formed of channels (see Fig. 42), placed back to back, with a clear space between them, and riveted together with covering plates. For a light traveller, the running wheels are often placed outside as shown, the axles passing through bearings G G, bolted or riveted to B.

Figs. 48 and 49 show a type of end cradle which is at once strong, cheaply constructed, and suitable for the heavier travellers. Fig. 48 shows the cradle in plan, with the ends of the two traveller beams, of the type seen in Fig. 43, bolted upon it; and Fig. 49 is the same in section in front of one of the wheels. Two joists of H-section A A are riveted together at a distance apart sufficiently wide to clear the travelling wheels B B, the union being effected with a covering plate C on top. End plates D D, riveted to the ends through angles *a* (Fig. 49), make a stiff boxed structure. Bearings E E, of cast-iron, bolted to A A, carry the axles of the wheels B B. F is the timber of the fixed

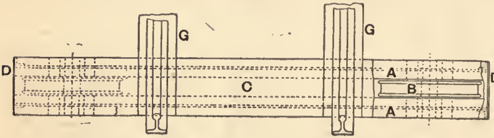


Fig. 48.—Plan of End Cradle for Heavy Traveller.

gantry, G G are the ends of the traveller beams. In heavy cradles the wheels are inside the framing as in Fig. 48, the arrangement outside, as in Figs. 40 to 42, being only adapted for lighter ones. In the heaviest travellers the end cradles are stiff boxed girders, built up with plate and angle iron.

It is not difficult to determine the strength of any longitudinal traveller beams or end cradles for a given span and load. A knowledge of mathematics, beyond that involved in the calculation of moments of inertia for given sections, is not necessary; and in the case of simple joists and combinations of channels even this can be dispensed with, because the leading firms supply particulars, which may be accepted as perfectly reliable, of the strengths of joists under different conditions of

loading. It is well, however, to be able to form a workable estimate of the strength of any vital portion of a traveller such as the beams, tie-rods, and axles, and examples of the calculations relating to them are here offered.

The margin of strength allowed in most parts of crane work is exceptionally large. In theory

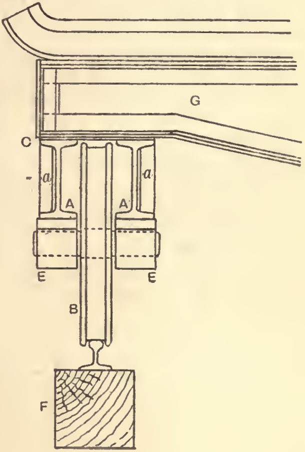


Fig. 49.—Section of End Cradle for Heavy Traveller.

the loading may appear to be dead loading; but in practice it is very severe live loading, consisting of impact, shock, stresses imposed suddenly and removed as suddenly, and wear and tear of the severest kind. All parts of a crane will fail at some time or other, under ordinary as well as under extraordinary stresses, and the practice of well-established crane-making firms is largely built

on the lessons taught by such failures. The knowledge gained by such experience renders it a by no means difficult matter to successfully design special cranes to meet special requirements. The following calculations are based on sound practice.

There is no law by which to fix the exact relationship between the depth and the span of a traveller beam. Different materials and methods of construction, together with different conditions of head room, considerably affect the proportion. Broadly speaking, an economical depth for a traveller girder is from $\frac{1}{15}$ to $\frac{1}{20}$ of the span. But to show the extent to which this proportion may vary under different conditions, two samples may be quoted, both of which are taken from existing cranes. One is a 10-ton traveller of 10-ft. span only. The girder section used is a rolled joist 10-in. deep, giving a proportion of $\frac{120}{10} = 12$ to 1. The other is a 6-ton traveller of 65-ft. span, having a plate and angle girder with double flange plates. The depth of the girder is 2 ft., giving a proportion of $\frac{65}{2} = 32{\cdot}5$ to 1. The section of a traveller girder may therefore vary considerably, provided its material is properly arranged to meet the stresses that come upon it. Traveller girders are usually considered as beams loaded in the centre and supported at the ends. The bending moment on the centre section of a beam of this kind is represented by the formula $\frac{W \times L}{4}$, where :—

W = weight or load.
L = length or span.

Care must be taken to add the weight of the crab or jenny to the load lifted, and the weight of the girders themselves must be taken into account as a distributed load. An example will make this a little clearer. Given a traveller to lift 10

tons on a span of 50 ft., with a girder depth of 2 ft. 6 in., what section should the girders have? Putting the weight of the crab at 4 tons, and the weight of the girders at 3 tons each, then:—Bending moment on one girder due to half the load, and half the weight of crab

$$\frac{7 \text{ tons} \times 50\text{-ft. span}}{4} = 87·5 \text{ foot-tons.}$$

Bending moment due to weight of girder =

$$\frac{3 \text{ tons} \times 50\text{-ft. span}}{8} = 18·75 \text{ foot-tons.}$$

Total bending moment at centre of one girder =

$$87·5 + 18·75 = 105·25 \text{ foot-tons.}$$

Dividing this bending moment by the effective depth of the girder, the load upon the flange area is found to be =

$$\frac{105·25 \text{ foot-tons}}{2\ 5 \text{ ft.}} = 42 \text{ tons.}$$

If the girders are made of steel, 6 tons per square inch may be safely imposed upon the flange area. This will mean an area of

$$\frac{42 \text{ tons}}{6 \text{ tons}} = 7 \text{ sq. in.}$$

to be made up in flange plate and angles. Using two angles, each 3 in. × 3 in. × $\frac{3}{8}$ in., and one plate 15 in. × $\frac{3}{8}$ in., the area will = area of two angles 3 in. × 3 in. × $\frac{3}{8}$ in. minus one $\frac{3}{4}$-in. rivet hole each = 3·65 sq. in. Area of one plate

$$15 \text{ in.} \times \tfrac{3}{8} \text{ in.} - \text{two } \tfrac{3}{4}\text{-in. rivet holes} = \frac{3·93 \text{ sq. in.}}{7·58 \text{ sq. in.}}$$

The width of the flange plate (15 in.) is just half the depth of the girder, and is a good proportion for traveller beams. The web plates in this case may be made $\frac{1}{4}$ in. thick. It is not usual to reckon on the webs taking any of the bending moment; they have their work to do in resisting shearing actions, and as a rule they have ample area for this. A web plate must have some body in it to

withstand buckling and corrosion; when these are allowed for, it will be found that the webs are safe enough in shear. Two webs should be used, and the girder should be built as a box section (Fig. 50). The underside of the girder may be curved to enclose a parabola in its outline. The depth at the ends can be made to suit their attachment to the end cradles.

Another way of calculating the sections of beams is from the moment of inertia of a section. This is similar in principle to that just used—namely, the dividing the bending moment by the depth—but it is not so quickly done, and the results are more exact. But the rule given and worked out is suitable for ordinary work.

To estimate the strength of an ordinary end cradle section is a simple matter. It is usually considered as a beam supported at the ends and loaded at the two points where the main girders are attached. The maximum bending amount to be sustained is that due to the weight imposed at A (Fig. 51), multiplied by the horizontal distance between A and B. The weight at A is made up of two items, one of them being due to half the weight of one main girder, and the other due to the proportion of the weight of the crab and load when right home at the end of the traveller (see Fig. 52, where T signifies tons, and the load is assumed to be 14 tons, consisting of weight of crab, 4 tons, with a load of 10 tons). To find the load at a in this figure, multiply the weight at b by the distance c, and divide by the span, thus:—
Load at a =

$$\frac{14 \times 46}{50} = \text{say 13 tons.}$$

As this load is carried by two girders, a load of $\frac{13}{2} = 6{\cdot}5$ tons is imposed upon the end cradle by one girder; half the weight of one girder must be

added to this, bringing the total up to $6{\cdot}5 + 1{\cdot}5 =$ 8 tons at point A in Fig. 51. The bending moment in this case is then:—

$$8 \text{ tons} \times 27 \text{ in.} = 216 \text{ inch-tons.}$$

The cradle section may be proportioned in the same way as that in the main girder, that is, by dividing the bending moment by the effective depth, and arranging a flange area to suit. If channel or joint sections are used, the modulus

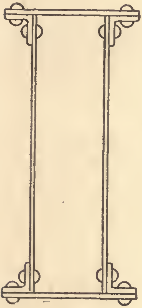


Fig. 50.

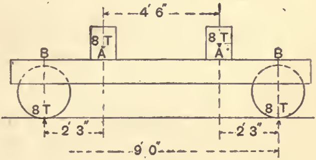


Fig. 51.

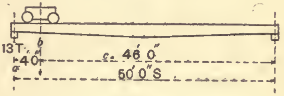


Fig. 52.

Fig. 50.—Section of Box Girder. Fig. 51.—Diagram of Load on End Cradle. Fig. 52.—Diagram of Load on End of Traveller Beam.

of the section multiplied by the stress per square inch on the material equals the bending moment acting upon the section. Thus, selecting say two channels, each 10 in. deep by 4 in. wide, having a combined modulus of section of 44, the stress per square in. will $= \frac{216}{44} = 4{\cdot}9$.

The wheel bases of traveller end cradles are generally about one-fifth to one-sixth of the main span, but this calculation is only approximate.

As a rule, if the cradles are well stayed, the longer the base the better the crane travels, as a short-base crane is apt to get jammed across the track.

Traveller beams of timber have to be trussed,

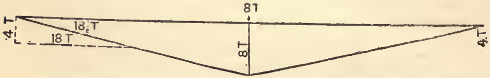


Fig. 53.—Diagram of Simple Truss with Central Load.

the trussing transmitting the bending stresses into tensional stresses in the tie-rods. The following examples will illustrate the methods of calculation adopted. Trusses are simple, or compound; and the loads are central or otherwise.

Consider first a simple truss with a central load. Take, for instance, a 10-ton traveller of 36-ft. span; the load on the beams would be about 16 tons, allowing 6 tons for the weight of crab, etc. This means 8 tons on each beam (Fig. 53). When the load is in the centre the reaction at each end of one beam would equal half the load on it—that is, 4 tons. With some definite scale, say $\frac{1}{8}$ in. to the ton, mark this reaction on a line perpendicular to the beam, then draw another line parallel to the beam until it cuts the tie-bar, as at left-hand end of figure; by scaling the length

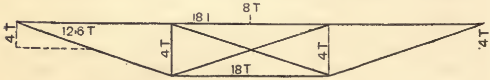


Fig. 54.—Diagram of Compound Truss with Central Load.

of this horizontal line the compression on the beam is obtained; by scaling the line corresponding to the tie-bar the tension on the bar can be measured, as in the figure.

The compression on the central strut is equal

to the load—that is, 8 tons. The proportioning of the sizes of the different members of the system is simply the equating of areas to safe loads on the materials used, care being taken that in the case of round tie-bars having screwed ends, the area under the thread of the screw is equal to the area of the main bar, unless, as in the case of small trusses, the bar area is slightly in excess in order to avoid the expense of swelling the end for the screwed portion.

Consider, secondly, a compound truss with the load central (Fig. 54), the load is as in the last example, and the reactions as before. The tensions in the end tie-bars will also be obtained in the same way as before. The compression on

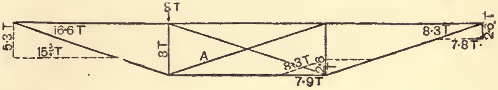


Fig. 55.—Diagram of Compound Truss with Load over one Strut.

the beam is most readily obtained by multiplying the action at one end by half the span, and dividing by the depth of the truss, thus:—

$$\frac{4 \text{ tons} \times 18 \text{ ft.}}{4 \text{ ft.}} = 18 \text{ tons.}$$

As this is the compression on the beam, it is also the tension on the bottom tie-bar.

The compression on the central struts is found by dividing the load on the beam by the number of struts, $= \dfrac{8 \text{ tons}}{2 \text{ struts}} =$ 4 tons compression on each strut. It will be noticed that the central counter-braces do not come into action until the load moves from the central position.

Consider, thirdly, a compound truss with the load directly over one strut (Fig. 55), and the load

will be as before. The reactions on the supports will be in inverse proportion to the distance of the supports from the load, so that there is one-third of the load = say, 2·6 tons on the farthest support, and two-thirds of the load = 5·3 tons on the nearest support. The tensions on the end tie-bars and compression on the beam can be obtained by the same method used for the simple truss.

The compression on the strut immediately under the load is equal to the load—8 tons; the

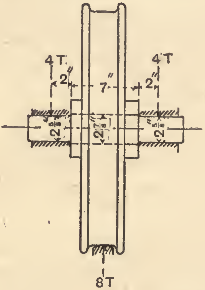


Fig. 56.—Calculation of Strength of End Cradle Axles.

compression on the other strut is equal to the reaction at the farthest support—2·6 tons. In the case now under consideration the counter-brace A (Fig. 55) comes into play as a tension member. The load upon it can be obtained by marking with the scale of tons the compression on the farther strut, using as a starting-point the junction of the three tie-bars with it, then drawing a line parallel to the counter-brace from the point obtained until it meets the horizontal bottom tie-bar; the length of this line represents the tension in the counter-brace; the length of the horizontal line of the

triangle formed gives the tension in the horizontal tie-bar.

The axles for the end cradles should have ample strength, or trouble will be experienced when travelling. They should be calculated for strength in the wheel and also in the bearings. Taking the diameter in the bearings first (see Fig. 56), it is necessary, in order to have a rigid axle, to reckon on a bending moment due to the load on the bearing = 4 tons multiplied by half the length of the bearing = 2 in., =

$$4 \times 2 = 8 \text{ inch-tons.}$$

Dividing this bending moment by 5 tons per square

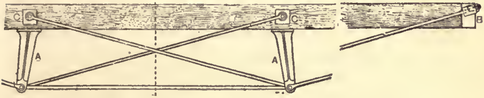


Fig. 57.—Struts for Timber Beams.

inch for wrought iron, a modulus of section will be required of $\frac{8}{5} = 1{\cdot}6$.

This is obtained by fixing the diameter at $2\frac{5}{8}$ (the modulus of section of a round bar is equal to diameter cubed $\times$ ·0982). The diameter in the wheel boss must be calculated by considering the axle as a beam the span of which is the distance between the bearings, and which is subjected to a distributed load if the wheel boss extends throughout the whole length as it should do. In this case, the bending moment is

$$\frac{8 \text{ tons} \times 7 \text{ in.}}{8} = 7 \text{ inch-tons.}$$

This happens to come out less than the diameter in the bearings, which would not do because the wheel must pass over the portion in the bearing in order to be placed in position. It is usual,

therefore, to make the centre portion of the axle slightly larger in diameter in order to facilitate the passing of the wheel into place, and also to form a slight shoulder on the axle to take side working, and so prevent the wheel working loose on its key from this cause. The driving axles must also be calculated for a twisting moment according to conditions, or method of driving.

Fig. 57 illustrates the method usually adopted for the strutting of timber beams. The struts A A are of cast-iron, designed to withstand compression. The tie-rods are of round bar, with forged eyes welded on, and drilled to receive the pins in the struts, the pins being in shearing stress. The main rods are attached at their outer ends to cap castings B on the ends of the beams. These ends of the rods, which are screwed, pass through holes cored in lugs on the outsides of the caps, and are each tightened with a nut. The pins for the attachment of the bracing rods to the timber beams pass through cast-iron plates C C bolted to the timbers. Flat bars are often used for tension rods, and timber for struts. The latter withstand compression as good as those of cast-iron, but they have a heavier appearance and are only suitable for small gantries. A builder who constructs his own timber work can save expense by using timber struts. Single strutting or trussing is adopted for traveller girders up to about 30 ft. span, double trussing between 30 ft. and 40 ft., treble trussing over 40 ft.

The platform arrangements of crabs and travellers vary with conditions. It is desirable to have a platform running along at least one side of a traveller, except in those of small dimensions worked from below. In the case of traveller crabs worked from an end cage, a platform along one side, for purposes of lubrication and examination, will suffice. The platform is frequently omitted

in steam crabs, the driver standing upon the foot-plate of the crab and running it back to the end of the gantry when the day's work is over; when head room is limited, boiler and tank are suspended from the crab, one on each side of the gantry.

In hand crabs, platforms for the men to walk on while turning the winch handles are generally put on both sides of the gantry. If this is not done, the crab must be surrounded with a platform, which is in one respect preferable, because the men are then better able to overlook the work

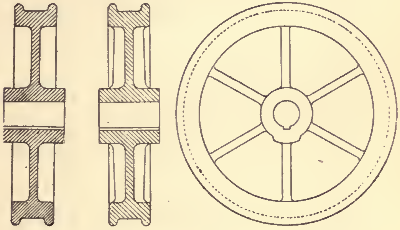


Fig. 58. Fig. 59. Fig. 60.

Figs. 58 to 60.—Sections and Elevation of Traveller Axle Wheels.

beneath. Sometimes, too, in addition, a narrow platform is run along each side of the traveller. Platforms should always be guarded with hand-railings. The railing is of gaspipe of about 1 in. diameter, and the stanchions are light forgings with feet for bolting to the timber, and holes for the gaspipe to pass through. The flooring boards are either supported on platform girders, which are made either of rolled joists or of timber beams, running in a longitudinal direction outside of, and parallel with, the main beams, or they are carried on iron brackets, which are built up of plate and angle and bolted to the beams.

The platform, when attached to and travelling with the crab, must go completely round it so as to afford access from one side to the other. It is supported on stiff angles, which are bolted to any convenient points of attachment on the crab framing, and it must be surrounded with handrailing.

The axle wheels of travellers are made either of cast-iron or of steel; in the heaviest travellers the centres are of cast-iron and the tyres of Bessemer steel, which are checked and shrunk on the

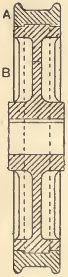


Fig. 61.

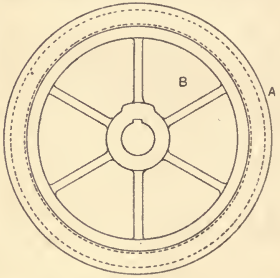


Fig. 62.

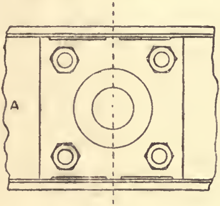
Figs. 61 and 62.—Section and Elevation of Traveller Axle Wheel.

centres. These axle wheels are shown in Figs. 58 to 62. The cast-iron or cast-steel wheel (Figs. 58 to 60) is made with a solid centre web in preference to arms. Arms are not so conducive to security of working as solid plate, because the metal in the rim is always in excess, as shown in the sectional views, partly for strength and partly to allow for wearing down of the tread.

The shrinkage stresses between the arms and rim are therefore not equal, and, though fracture may not occur at the time of casting, it is likely to happen afterwards under moderate stress, be-

cause the metal is in a permanently overstrained condition. The evil may be lessened by careful regard to proportioning and by the use of large radii. But these precautions are often neglected, and therefore it is always safer, except for very light loads, to have plated wheels; but even for light loads also it is best to be on the safe side.

The plated wheel is frequently stiffened by casting arm-like ribs on both sides of the plate (Fig. 60). These ribs give additional support to the rim, which is subject to much stress not only from the dead load, but also from diagonal stress acting



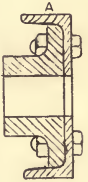


Fig. 63. Fig. 64.

Figs. 63 and 64.—Cast-iron Bearing.

against the flanges, due to cross working of the traveller or crab. The difference between an iron and a steel wheel, each of which is made as in Figs. 58 and 60, is that the latter for equal loading may be about from 30 to 50 per cent. lighter than the former. It is not a usual practice to turn the treads of wheels, but it is often insisted on in high-class work, and conduces to smooth running.

The compound wheel (Fig. 61) is only required for heavy pressures and severe duty. Fig. 62 shows another view of Fig. 61. It is the best possible form of wheel, but is expensive. The tyres A are weldless, rolled from Bessemer steel blanks, and these are turned and bored carefully to suit

the turned cast-iron centres B. The turning fit is sufficiently easy to permit of the tyre, when at a low red heat, dropping over the raised check on the rim. When dropped over in this condition, the tyre as it cools grips the centre so tightly that bolt or rivet fastenings are not required. The depth of the check averages $\frac{1}{16}$ in. The centres must be massive and solid webbed; arms are quite unsuitable. Both web and rim must be thick, as shown proportionally in the figures.

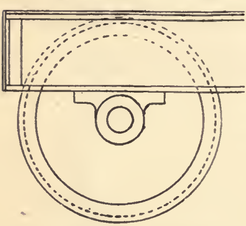


Fig. 65.—Cast-iron Bearing.

Rails used for travellers and traveller crabs are of the flanged type. They are bolted direct to the wood or to steel beams. In the latter case wood packing is frequently inserted. They may be bolted down direct or through clips pressing on the rail flanges.

The cast-iron bearings for the axles of end cradles are usually of the forms shown in Figs. 63 and 64 (plate bearings) or Fig. 65 (dead-eye bearings). These last are easily fitted, and as the motion of the axles is but slow, the bearings are seldom brass-bushed except in power travellers. Bearings of the type shown in Figs. 63 and 64 are of cast-iron, riveted and bolted between the channels A, chipping strips being used, because channels that are nominally alike vary slightly in width and in thickness of flange; by using strips, therefore, the work of chipping to a fit is often diminished. The bearings are properly bored after being fitted and bolted into place.

CHAPTER V.

APPLYING MOTIVE POWER TO HOISTING MACHINERY.

THE methods by which the motive power is made to operate travellers and crabs may now be considered in detail.

Beginning with the simplest, Fig. 66 shows the design of single gearing adopted for the longitudinal travel of travellers operated from below, a rope wheel turned by an endless rope depending therefrom. Its shaft operates the bevel pinion B, and wheel C; B has its bearings in the boss of the bracket D bolted to the traveller beam E; C is keyed on the shaft F which runs the whole length of E, having its bearings at G G, which are also bolted to E. There will be one or more intermediate bearings like G at intervals along the beam to support F. Two pinions H H at the ends of F drive wheels J J, keyed on the axles of the travelling wheels K K. The travelling wheels at the other end simply follow those, being ungeared. In heavy travellers, double gear is used instead of the single gear shown in Fig. 66, an intermediate pinion and wheel coming between H and K.

The rope and chain wheels A, used for operating travellers from below, are always as light as it is possible to cast them. Metal massed in these wheels would be in the wrong place, because there is practically no stress on them, and it would only add to dead load on the shafts and beams. These wheels are worked by ropes and by chains; a wheel with a smooth rim being used for rope, and one with a nibbed rim for chain, because a rope will bite on a smooth rim, but a chain will slip. The general proportions of both wheels are alike,

and the same patterns are generally used, the only difference being in the rims.

Figs. 67 to 69 illustrate the general outlines of

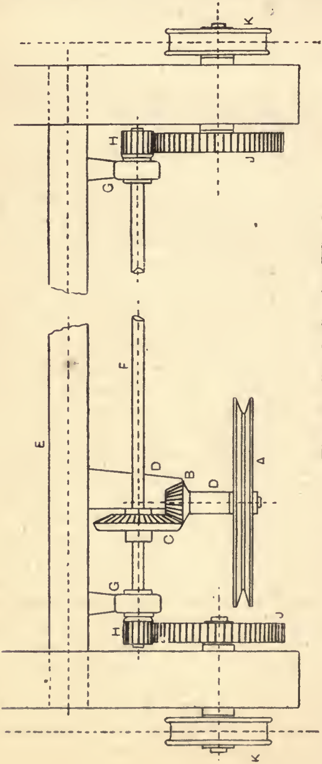


Fig. 66.—Single Gearing Wheels.

chain or rope wheels. The arms are light, and the rim is of V-section, with a radius in the bottom, so that the rope or chain instead of lying close to the bottom of the rim is gripped between the sides of the V (Fig. 70), which arrangement materially assists the bite. Sometimes rope wheels are

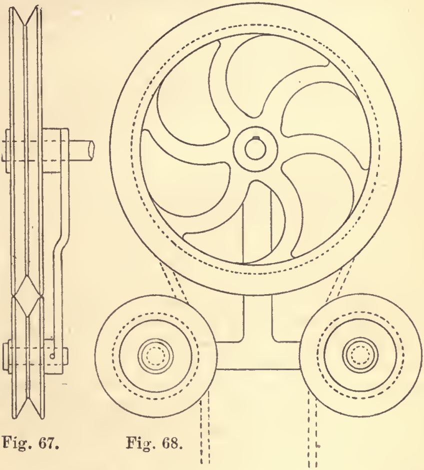


Fig. 67. Fig. 68.

Figs. 67 and 68.—Rope or Chain Wheel with Guide Pulleys.

"waved"—that is, the V looked at edgewise is curved lengthwise at the bottom (Fig. 71), so that the bending or biting effect between the rim and the rope may be increased. This is a desirable provision when the ropes and the wheels are large, but it is not necessary for small ropes.

The nibs cast on for chains are of the form shown in Fig. 72. They are about ⅜ in. wide in the

middle, standing about $\frac{1}{4}$ in. high, are rounded off towards the ends, and are placed from $1\frac{1}{2}$ in. to 2 in. apart. Fig. 72 is a longitudinal section of the V-rim, Fig. 73 is a cross section, and Fig. 74 is a

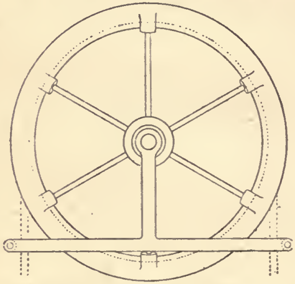


Fig. 69.—Rope or Chain Wheel.

plan. To accommodate a large chain, the rim of the wheel should be cast with recesses into which the links of the chain will drop bodily (Fig. 75). The pitching out must be accurately done, otherwise the chain will ride in the wheel instead of dropping into the recesses, and the difficulty of obtaining this accurate fitting increases with the size of the wheel, or with the arc of contact with

Fig. 70.

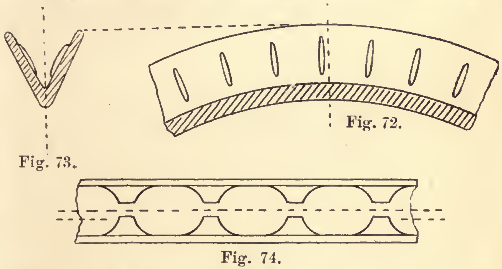
Fig. 71.

Fig. 70.—Section of Rope in V-rim of Pulley. Fig. 71.—Rim of Waved Rope Wheel.

the chain. The best way is to pitch the centres of the recesses accurately, and to allow considerable clearance between the chain links and these recesses.

The dimensions of rope and chain wheels vary from 2 ft. to 5 ft. in diameter. The metal in the rims ranges from $\frac{1}{4}$ in. to $\frac{3}{8}$ in. thick, and the arms are made as light as possible, consistently with reasonable rigidity. If large bosses have to be cast, as when the wheels of this kind have to fit over sleeves, the arms being cast also, the shrinkage of the bosses is liable to cause fracture in the arms. It is better, therefore, to split the boss in the mould and bond it subsequently.

Figs. 68 and 69 illustrate the two general



Figs. 72 to 74.—Longitudinal Section, Cross Section, and Plan of Nibbed Rim.

designs on which rope wheels are made. The first is of cast-iron, with curved arms, this curving diminishing any tendency to fracture; the second is made with wrought-iron arms cast into rim and boss, and hence is termed a spider wheel. Fig. 68 is suitable for wheels up to about 2 ft. 6 in. diameter, Fig. 69 for the larger wheels. In both figures the details are suitably proportioned. The bite of a rope on a small pulley is increased by the employment of guide pulleys as in Fig. 68, which are not necessary in larger wheels. But it is proper in any case to have swinging rope guides, as in Fig. 69, to coerce the rope and prevent it

from getting off the pulley groove during working. This guide is a T-shaped forging dependent from the spindle, being bored at the top to fit over the pulley spindle, and maintained at a suitable distance by distance pieces at the ends of the bottom horizontal. The rope passes between the two horizontal members. The manner in which the T-shaped sling is supported and bent inwards to the wheel is seen in Fig. 68.

One disadvantage of the crab worked from below is that ropes or chains hang down in the way of the work, and of the workmen on the floor below; but this would only be objectionable in some cases. This type of crab is suitable for occasional service, but for constant duty the types before referred to are preferable.

The numerous class of travellers which are operated from above embrace the square-shaft, both hand and steam; the cotton-rope; and the electrical types. The square-shaft traveller is the oldest; the steam comes next in point of time, and is followed by the cotton-rope and the electrical types. The cotton-rope traveller is steam-driven, but the engine is not on the traveller or crab, but is situated elsewhere. The square-shaft type is, in the hand travellers, driven from the crab gearing, as also are the steam travellers proper; or a steam-driven square gantry shaft will operate both the traveller and the crab. In some few cases the longitudinal movement of a traveller is not worked from the crab, but by means of gearing on the end cradles. This is not a good arrangement, because it entails loss of time, though the construction of the crab is simplified.

When putting up a traveller, the choice of type and of motive power must be largely governed by the conditions which exist in the factory or works. If sufficient engine power is available, it might

be better to utilise it for driving by rope or square shaft. If there is a dynamo already in the place, or if it is intended to set up a dynamo for any purpose, such as lighting, the same machine or another might also be employed for driving the traveller.

In increasing motive power when that power is steam, the cost of shafting and belting, etc., for transmission, and of oil and repairs, becomes a serious item, while the extension of electrical power involves nothing more than the laying down of new dynamos, motors, and conductors. The

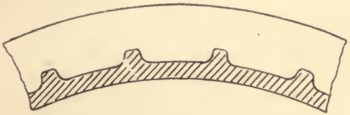


Fig. 75.—Longitudinal Section of Wheel Rim with Cast Recesses.

waste due to friction in hundreds of yards of shafting and shaft fittings is enormous; that due to heat losses in dynamos and motors does not cost money for renewals, as in the case of steam-driving.

For hoisting, even more than for the driving of machine tools, it is desirable that electricity should be employed rather than steam power transmitted by belts, shafts, or ropes, because hoisting is in most shops of a very intermittent character, and belts, shafts, or ropes run continuously. The electrical plant, requiring no time to develop power, is, therefore, far better fitted for such intermittent work. Electricity is, too, more adaptable and more economical than steam, as motors can be set down and worked anywhere; but a steam engine must be near its boiler, because the farther it is away the larger is the percentage of

wasted steam; it must also be kept at work, with an expenditure of power out of all proportion to the results, though only one or two machines out of a shopful are running.

In smoothness of running, a high-speed crab, whether driven by rope or electricity, is superior to a steam-driven crab, because to the latter is transmitted from the engine a more or less oscillatory motion. But the worm-drive on high-speed travellers is always very smooth, while the longitudinal travel is equally so. Another advantage of high-speed driving is that the load due to the crab, which is dead load on the beams, is lessened by the absence of the boiler, engines, and tank. This load, though advantageous in a balance crane, is undesirable in a crab. There is little difference in the motor arrangements, whether belts or gear wheels are used for transmitting motion from the end of a traveller to its crab. The substitution of one motor method for the other can be easily effected at a small cost.

If a quick-speed power traveller is required, and the laying down of electrical power at some future time is contemplated, the best traveller to obtain is one of the rope-driven type, either with belt or with clutch arrangements. In such circumstances, a motor can always be substituted for the rope drive; but, with a steam crab, the cost of conversion either into rope drive or into electrical drive would be nearly prohibitive, because engines and boiler would be useless, the bevel-gear between the square shaft and the crab would have to be replaced with worm gear, and the whole of the driving and reversing gear at the end, whether wheels or belts, would have to be entirely new.

The square-shaft drive is suitable for gantries of moderate length and for moderate speeds. But for long gantries and high speeds it is not so well

suited as the rope drive. The latter can be of unlimited length, the former should not be more than about 200 ft. Rope driving is quieter than shaft driving. Wire, hemp, and cotton are used; and speeds range between 2,000 ft. and 5,000 ft. per minute, 2,000 ft. being a usual rate.

The steam traveller is the best type for use out-of-doors in yards, docks, and harbours; but it is not desirable inside buildings, because of the sulphur, steam, and dust given off. For such situations any of the other methods of driving are preferable.

Square-shaft and electrically driven travellers are sometimes made to work from below, with dependent chains. In such cases, the chains pass over pulleys, from which the operating clutches on the traveller are controlled. Such an arrangement is not desirable, and is only adopted when the work is of so intermittent a character that there is not sufficient of it to keep a man constantly aloft.

Fig. 76 shows the general arrangement of the working of a square-shaft traveller from a crab. The same method will serve alike for hand or steam. Substantially the same arrangement would be used if the traveller were driven from a square shaft running down one of the gantry beams, the direction of driving being reversed. In Fig. 76,

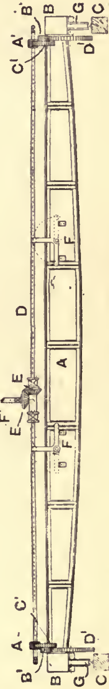


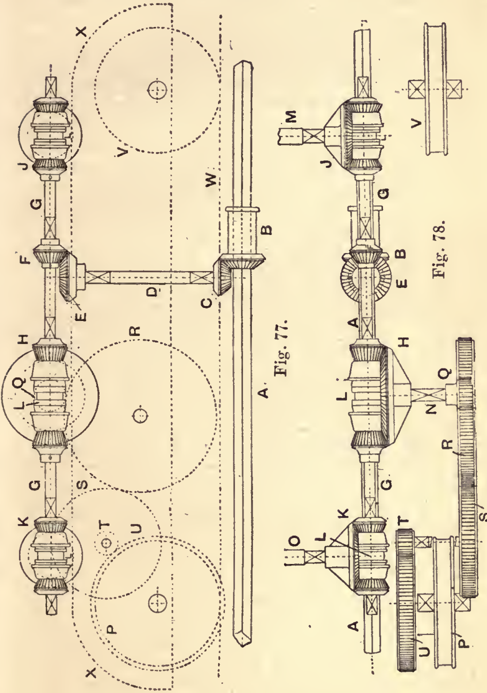
Fig. 76.—Square-shaft Traveller.

A is one of the traveller beams, single-webbed and fish-bellied; B B are the end cradles, plated, against which the beams fit by abutment; C C are the gantry beams against the walls of the shop; D is the square shaft driven by the sliding or sleeve-bevel wheel E, from the crab gear through F′. The wheel E travels with the crab, having its bearings in a bracket on one side of the crab, the journals being indicated by diagonal lines, and the revolution of the wheel turns the shaft D in its bearings at the ends of the beam. The shaft D is supported by the tumbler bearings F F, which have their bearings on the sides of the beam A. The radius described by the bearings when knocked over by the passage of the wheel E is indicated by dotted half-circles. The motion of the shaft is communicated to the running wheels G G through two sets of gear, one at each end. Each set comprises two pinions A′ B′ and two wheels C′ D′, by which power is gained. The wheel D′ is keyed in the axle of G.

Heavy shaft-driven travellers are sometimes driven by bevel wheels and reversing clutches, arranged at one end of the gantry. There is an advantage in the adoption of such an arrangement, besides that of permitting the attendant to overlook properly the operations going on below, as it is one in which rope or electrical driving can be afterwards substituted with the minimum of expense. In this type of traveller the rotation of the square shaft is transmitted through bevel gearing to the shaft which is driven parallel therewith, above the end cradle, and the substitution of a motor for the square shaft would be the only alteration necessary, the reversing bevel gearing being retained for the operation of the several motions.

When a traveller and a crab are driven in this way from a square shaft running down one of the

gantry beams, the arrangement referred to, and one which is frequently adopted, is that shown



Figs. 77 and 78.—Square-shaft Driving Gear.

in Figs. 77 and 78. Fig. 77 shows an end elevation of the gear; Fig. 78 shows a plan view, all adjacent details being omitted, and the location of

the journals being indicated by diagonal lines. In this design each distinct motion is operated by a separate set of gears on one shaft on the end of the traveller, over the end cradle.

In Figs. 77 and 78 A is the longitudinal down gantry shaft, and B is the bevel wheel which slides on the shaft with the movement of the traveller. This wheel gears into another bevel wheel C, which has its bearing in a bracket bolted to the end cradle, the shaft D of which has a bevel wheel E at its upper end, which gears with and drives a bevel wheel F on the shaft G, that carries the different gears for actuating the several motions—that namely of longitudinal travelling H, of cross-traversing J, and of hoisting K. In these gears the mode of operation is that of friction cones, or friction clutches. The sliding of either of the double-ended clutches L L L to right or left drives the shaft in one direction or the other. The bevel wheels run loosely, the clutches only having keyways which slide on feather keys in the shaft.

When the clutch L is in gear with the clutch on a pinion the two are as one, and are driven by the feather key. The pinion which is engaged with the clutch drives the larger wheel on the shafts M N or O, which operate the several motions through other wheels and pinions. The shaft N drives the running wheel P through the intermediate gear Q R S T U, and the shafts M and O operate the traversing and lifting motion through sliding worms, and worm wheels on the crab. All the bevel wheels are half shrouded—that is, they have flanges or caps reaching to the pitch planes, and turned on their edges, and these roll against one another in continual contact during the operation of the gears. The advantages are twofold—the strength of the teeth is slightly increased, and the motion is rendered smoother and more regular. These flanges are an important

detail in good practice, which should never be omitted in high-speed hoisting gearing. The same addition is to be observed in the spur wheels Q to T. The wheel V is not driven by gear, but trails only. The rail level is indicated by the dotted line W, and the end cradle by the dotted outlines X. A projected view of wheel V is shown.

The gantry shafts, which are used for driving to or from traveller crabs, are almost invariably made of square bar iron or steel. Steel is generally used now, because a smaller size can be used

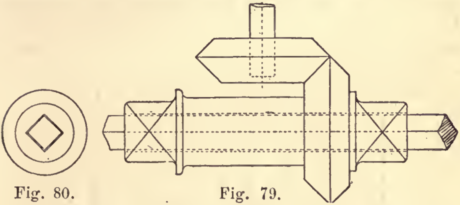


Fig. 80. Fig. 79.

Figs. 79 and 80.—Sliding Pinion on Gantry Shaft.

than in wrought iron, thus reducing dead weight while retaining equal strength. The shafts are made square because they have to drive or be driven through bevel gearing, one wheel of which must revolve, either driving or being driven by the shaft as it revolves. The sliding wheel is cored and slotted, or cored only, and filed out to make an easy sliding fit on the shaft, but not so easy as to permit of much slop and backlash (Figs. 79 and 80). These shafts are not tooled, but are left black. A coarse file may be passed over them, but nothing more. As the shafts are generally longer than the standard length of bars, one, two, or more joints have to be made in them. These are of the scarf form, that shown in Fig. 81 being as good as any other, and the most easily

made. In making such a joint as this, the scarfs are formed by slotting in a machine, and the rivets have countersunk heads. The size of bars used will range from $1\frac{3}{4}$ in. in light hand and power travellers, to $2\frac{1}{2}$ in. and even 3 in. in the larger power travellers.

As the shafts are of great length in proportion to diameter, it is necessary to afford them support at several points intermediate between the end bearings. But, as they have to be traversed constantly from end to end by the sleeve bevel wheel which slides along, the bearings cannot be rigid, but must be of a type which can be easily moved aside momentarily to allow the wheel to pass.

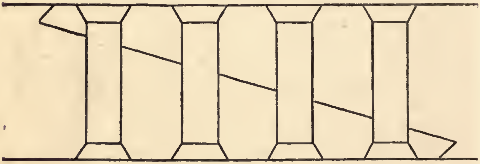


Fig. 81.—Scarf Joint in Shaft.

This is the tumbler type, and is found in modified forms in all travellers. Some of the tumbler bearings are much more complicated than others, and are the subject of patents. They all belong to one of two types; one is that of a lever or levers thrust over by the passage of the bevel wheel removing the supporting bearing from the shaft momentarily, the support being returned automatically as soon as the wheel has passed and left the bearing clear. The other is a bearing moving vertically, thrust downwards by the passage of the wheel, and returning immediately afterwards.

The commonest type of tumbler, which is cheap and efficient, is shown in Figs. 82 and 83. It consists of a bell crank lever A, pivoted in a bearing

B, on the sides of the gantry beams C, and having recesses at its free ends to receive the turned portions of the shaft. As the crab comes along it knocks over the bearing which is uppermost, causing the horizontal lever arm, with its bearing, to rise up and take the position of the displaced vertical bearing immediately after the passage of the wheel. The lever arms are maintained in a vertical position by the resting of the horizontal arms upon supports bolted to the traveller sides,

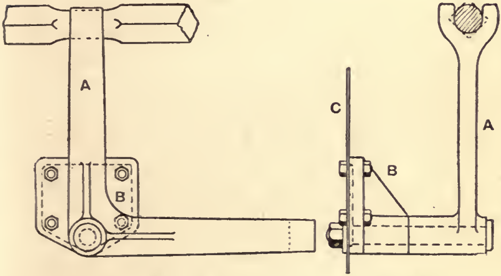


Fig. 82. Fig. 83.

Figs. 82 and 83.—Tumbler.

seen in Fig. 76. The mechanism is efficient; but the details will vary in different cases. In the lighter travellers the ends of the tumblers are simply cored out, as shown in Figs. 82 and 83, and not machined, but cleaned out a little with the file. For the rapidly revolving and heavy shafts, bearings are made of brass or phosphor bronze, bored and fitted into the ends of the cast-iron tumblers.

The driving of travellers and crabs from a square gantry shaft seems a somewhat clumsy device. The shaft must be heavy and of large

size to resist torsional stress, and it must be supported in tumbler bearings at intervals. This increases weight and expense, and absorbs much power. Moreover, very long gantry shafts are objectionable, because of their tendency to twist and their great weight. It is for these reasons that the cotton rope and electrical drives have found so great favour.

There is little difference between the gearing of an electrical and of an ordinary crab or traveller, and electricity can be applied to almost any well-constructed hoisting machine, with a few necessary alterations. The traveller picks up the electric current from a conductor running down the length of the shop, which through a motor or motors on the traveller drives the first motion shaft in place of the cotton rope, or square shaft, of an ordinary machine.

A common difference between a square-shaft traveller and a rope or electrically driven traveller is that the shaft is driven at a slow speed, and that the latter two are driven at a very high speed. In the first case it is not necessary to effect much, or even any, reduction in speed between the shaft and the crab ; in the latter two cases it is necessary to do so, in order to bring the rates of lifting, travelling, or traversing, within workable and safe limits.

A rope must be driven at a high speed to develop its dynamical force, and an armature must generally revolve at a high speed. Ropes run at rates ranging from about 1,500 to 3,000 ft. per minute, and armatures revolve at from 700 to 1,200 ft. per minute. The reduction of speed between the first driving shaft and the crab is nearly always effected by worm gearing, in some cases, however, by spur gearing. General practice favours the former, but there are exceptions, and single-threaded worms have, until recently, been

most generally used; but double and even treble-threaded worms are now successfully employed, the idea being to reduce the excessive friction which occurs between the gears. Single-worm friction, however, has its advantages, and the method has its advocates, because the friction is so great in amount that the crab can never run and turn the worm through the wheel, which can happen in double- and treble-threaded worms. When the latter are used, therefore, it is necessary to fit a brake to the gear.

The reversing mechanism for each motion (longitudinal, cross-traverse, and lifting) must, both in shaft- and rope-driven travellers, be effected either through belting or clutches—the clutches being of the general type and arrangement illustrated by Figs. 77 and 78, and the belting, when used, being open and crossed for each motion, in order to run the operating shafts in reverse directions. In electrical travellers each of these methods is employed, as well as another method which is not practicable with square-shaft-driven travellers—namely, the use of reversing motors, but the opinions of engineers and electricians are divided as to the advantages of this method. One advantage is that the use of reversing motors does away with the intermediate gear of clutches and wheels, or belts and pulleys.

When it is a question of converting an existing rope- or square-shaft traveller, it is perhaps as well to employ a continuous-running motor; but when a new driving system is being designed, the knocking out of the reversing gear is worth consideration. Electricians generally object to the use of reversing motors, but the experience of several competent engineers has demonstrated their practical utility in the driving of overhead travellers.

There are two ways in which the motions of travellers and crabs are regulated by the atten-

dant; one is by means of levers, another through hand wheels. These may operate friction clutches in gearing, or belts. Clutches are either of the claw or of the friction type, the latter running with less shock than the first. Claw clutches are not suitable for the high speeds of rope- or electrically-driven travellers, notwithstanding that they are used for slow-running cranes.

Practice is pretty equally divided between belt driving and friction cone driving for power, rope, and electrical travellers. Both are durable; both have the advantage of effecting a gradual start and a gradual stoppage, and both, being operated by levers or by hand wheels, are under perfect control; both possess the very desirable characteristics of yielding under excessive and dangerous stress, the clutches slipping within each other, and the belts slipping on their pulleys, while possessing ample grip for all legitimate duty.

The sizes of cones, the angle of cones, and the length of drive of belts, cannot be determined by theoretical considerations, but are settled solely by practice, according to the duty which they have to perform. The holding powers of clutches, 6 in. or 8 in. in diameter, is sufficient for loads of from five to ten tons, and the angle of cone is about 1 in 6. If the angle were much less than this it would cause seizing; if it were much greater it would impair the frictional power. For operating these clutches, either a hand lever or a screw movement is employed. The lever is more rapid in its action, but the screw holds more securely, and should be generally adopted.

Levers alone are used for belt shifting. Belt driving is rather more gradual as regards increase of speed than clutch driving; but trouble may occur in consequence of the slipping of the belts, which is generally caused by too short a drive. A long drive, which is easily obtained in the

belting for most machine tools, cannot be got on a traveller. But the short drive should be used under the most favourable conditions possible, and the belts must be kept tightly strained; this is not the best way of running a belt, it is true, but it is the only way possible in traveller driving. The best kind of belting must be used, for inferior qualities will give perpetual trouble by stretching, fraying, and cracking in consequence of the high speed at which they are run.

The arrangement of the belting varies in travellers by different makers. But generally there is a first motion drum, and from this all the traveller and crab motions are driven. The lifting shaft is driven by two pairs of pulleys, each pair being fast and loose. The larger pair is used for lifting, the smaller pair for lowering—the reversal of the latter being accomplished by crossing the lowering belt. The traversing shaft is driven by three pulleys and two belts, one belt open and the other crossed, driving on the outer pulleys, the middle pulley being the loose one. The longitudinal travelling is done by a drive on to pulleys on an intermediate spindle, and gear wheels are used to reduce speed and gain power. Such an arrangement of belt driving will be suitable for a motor-driven or a rope-driven traveller. With a motor drive the end pulleys will be belt connected; with a rope drive the rope will run over grooved pulleys in the place of the belt pulleys.

Electrical crabs are driven through one or more motors. The former method is the most common. The motor is set on one end of the traveller, and the motions of the crab are operated through levers. The object in using three motors is to have each one proportioned to the particular work which it has to do, that is, lifting, travelling, and cross traversing. No intermediate gear is required. Motors are connected to the first motion

drum by means of a belt drive. The objection to this is the shortness of the drive, which is liable to cause considerable slip. The motor is usually fixed on a sliding base plate for adjustment.

A method of driving permitting instant connection with, and disconnection from, the motor, is the Hollick friction gear, by means of which the movement of the motor can be instantly switched off from the hoisting drum. The armature shaft is provided at one end with a paper-covered friction pulley. This is run in contact with a cast-iron pulley on the same shaft as the first pinion which drives the gear for the hoisting drum. The two are kept in contact by means of a third pulley, which is maintained in contact with the paper pulley by means of two adjustable links.

When the centres of the pulleys are in line the pulleys are in frictional contact. But a slight movement of the outer pulley up or down will break the contact, and the driving pulley will cease running, being out of contact with the paper pulley on the armature shaft. Contact is broken by levers and links. The pushing over of a large lever moves the short levers and the links, causing the centre of the outer wheel to turn in an arc round the centre of the driving-wheel shaft, thus throwing the first pulley out of the line of centres and breaking the contact.

Very few data are as yet available for estimating the relative economy and efficiency of travellers actuated by ropes and by electricity, but so far the balance of evidence is in favour of electricity. Some practical men believe that effective electrical hoisting machinery has yet to be designed. Electrical driving is at present in the crude stage; instead of adapting machines to its special requirements, it is used for machinery that has been designed for an altogether different motive power. An analogous case is that of the

early railway carriage, which was a very slight adaptation of the then familiar stage-coach. Up till recently the practice has been to drive all motions of a traveller from one motor; it is now beginning to be understood that this is somewhat akin to driving a machine from shafting and pulleys, or a crane from a flyrope or square shaft, each of which is running constantly, whether the machine or crane is, or is not, being used. At any rate, engineers are feeling their way to better designs, and it is probable that in this, as in other departments of engineering, much may be learnt from America, where the advantages of electrical driving are more appreciated than they are in this country, and where it is more extensively applied.

The power required to drive the ropes alone for travellers is considerable, and this is constant even when the traveller is at rest. Mr. John Barr found that the power to drive the ropes for two travelling cranes, with the ropes running at 2,200 ft. and 1,570 ft. per minute respectively, varied from 5·9 indicated horse-power in the first to 6·3 indicated horse-power in the second, per 100 ft. length of shop. The ropes formerly used for driving the travellers in the erecting shop at Horwich ran at a speed of 3,880 ft. per minute. These were each $1\frac{5}{8}$ in. diameter and 600 ft. long, weighing $3\frac{1}{2}$ cwt., and each absorbed with its pulleys 15·5 horse-power.

The power absorbed in driving shafts and belting nearly always forms a large proportion of the total power used. The table on p. 92 will give some idea of this.

One of the objections sometimes urged against electrical driving is that the attendants lack technical knowledge; and a graver accusation is that the original designers of the machines do not possess that theoretical and practical acquaintance

Power Required to Drive Shafting in Different Works (*Flather*).

Name of Firm.	*Nature of Work.*	*Total.*	*To Drive Shafting.*	*Per cent. to Drive Shafting.*
J. A. Fay & Co.	Wood-working machinery	100	15	·15
Union Iron Works	Engines, Mining machinery	400	95	·23
Frontier Iron and Brass Works	Marine engines, etc. ...	25	8	·32
Baldwin Locomotive Works	Locomotives	2,500	2,000	·80
W. Sellers & Co. (one dept.)	Heavy machinery	10[illegible]·45	40·89	·40
Pond Machine Tool Co. ...	Machine tools...	180	75	·41
Yale and Towne Co. ...	Cranes and locks	135·05	66·81	·49
Ferracute Machine Co. ...	Presses and dies	35	11	·31
Bridgeport Forge Co. ...	Heavy forgings	150	75	·50

with the subject which is absolutely necessary to success in machine construction. The designing of a good electrical traveller requires the co-operation of the electrician and the mechanical engineer; neither of them alone appears to be able to design an efficient traveller.

The almost general practice hitherto has been to copy a rope-driven or square-shaft traveller in all, or nearly all, its details, and then to substitute the motor for the usual method of driving. This

plan may not be open to objection when it is required to convert existing travellers, but it will not be on such lines that the successful machine of the future will be arranged. In such machines it is probable that intermediate gear will be abandoned, and that one motor will drive one particular motion, each being reversible by the same motor, without intermediate gear. Further, in an electrical traveller provision must be made for the gradual starting of the machinery. This is accomplished by inserting a resistance, which permits the flow of only just sufficient current to start the motor. As the load is taken on, the resistance is gradually cut out, either by the movement of the switch in the hand of the attendant or by an automatic governor. The prevention of sparking under wide variations of load is an essential requirement, and so also is the making of the brushes self-adjusting for wear. In such matters the electrician can render valuable aid to the mechanical engineer.

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